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Discover why this molecule is the key to life

SURVIVAL GUIDE
SAS expert reveals how to conquer the wilderness

THE WORLD'S DEADLIEST PREDATORS

HOW THE MOST LETHAL ANIMALS CAN KILL IN SECONDS

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Levitating pods & 700mph trains

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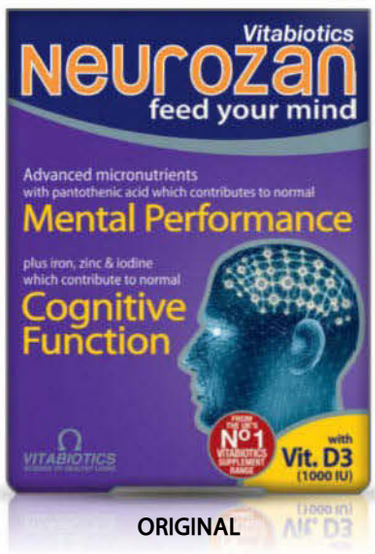
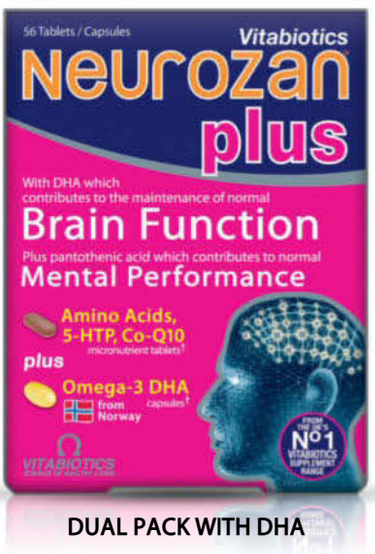


ORIGINAL



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VITABIOTICS
SCIENCE OF HEALTHY LIVING

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ISSUE 76

WELCOME

The magazine that feeds minds!

Page 56
Discover the future of commuting

It's been 40 years since *Jaws,* but moviemakers still cast sharks as the villain, with the brainless *Sharknado* and *Ghost Shark* (the spectre that attacks from toilets). The man-eating image endures, despite the fact that you're more likely to be struck by lightning than attacked by a shark!

I'll never forget interviewing marine biologist Richard Elliot, who was a good friend of the late Peter Benchley, author of *Jaws*. He recalled reading drafts of the book and saying, "This is nonsense, sharks don't eat people," and Benchley would reply, "It doesn't matter, I'm writing fiction." It wasn't his intention to spark a vendetta against this creature, but he ended up doing just that. Wracked with guilt, Benchley became a dedicated conservationist, but the damage was already done.

Rather than fear sharks, we should revere them, and this issue celebrates the incredible design, senses and hunting tactics of not only sharks, but a whole host of other predators at the top of their food chains. It's survival of the fittest, and these animals are shining examples that we should strive to protect.

Jodie

Jodie Tyley
Editor

Meet the team...

Andy
Art Editor
It's hard to believe that the Earth was once hit by another planetoid, just imagine cleaning up the mess after that!

Siobhan Maguire
Production Editor
I'm not the most outdoorsy person, but with the Survival Guide to hand, I'm sure that I could make it out alive!

Phil
Staff Writer
This month's deadliest predators feature hasn't put me off a safari holiday, but maybe a pet komodo dragon is a bad idea.

Jackie
Research Editor
Water, water everywhere... but less than one per cent of it is actually drinkable so don't go chasin' waterfalls.

Jo
Assistant Designer
This was my last issue before I start designing the sister magazine, **All About Space**. I've loved every minute and learnt a lot of facts!

Jo
Features Editor
The robot cocktail bar on the Anthem of the Seas was where I spent a big chunk of my holiday this summer!

What's in store

Check out just a small selection of the questions answered in this issue of How It Works...

What is the cause of anxiety? **Page 46**

Why is Lake Abraham flammable? **Page 30**

How do racing simulators work? **Page 62**

How are man-made waves formed? **Page 55**

How does the Mars lander work? **Page 72**

How did the Incas live? **Page 74**

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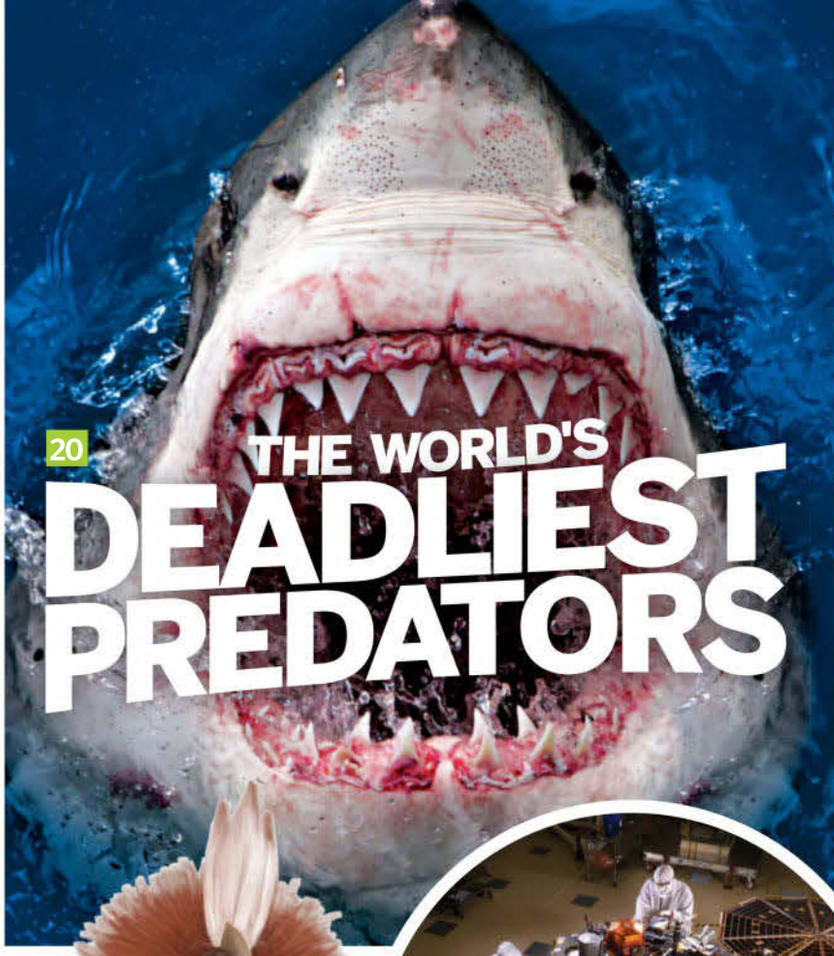

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Meet the experts...

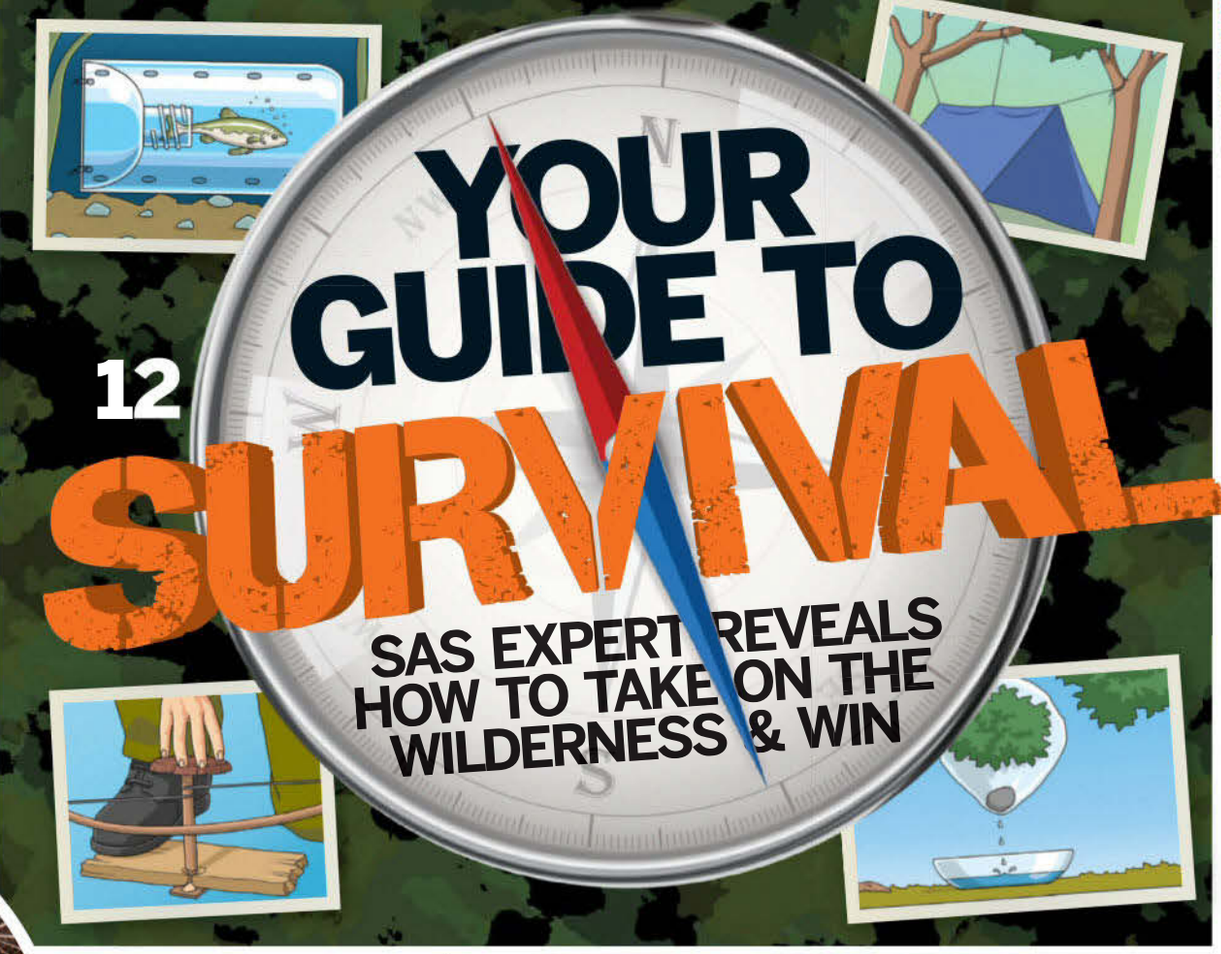
Laura Mears
It's amazing to think that the same water we drink today was here at the same time as the dinosaurs. That's just one of the mind-blowing facts in Laura's feature about the life-giving liquid that comes out of our taps!

Gemma Lavender
This month, **All About Space** magazine's Gemma reveals what happens in a cosmic pile-up on page 64. She also stars in our YouTube video about Pluto!

Tim Williamson
The Bell UH-1 Iroquois has its own Facebook page, which declares it "the greatest helicopter in the world!" It even has over 16K Likes. Find out why on page 80, where Tim explains all.

Lee Sibley
The Editor of **Total 911** reveals how we'll be travelling to work in the future, over on page 56. We can't wait to ditch our cars for levitating pods that soar above the city!

Ceri Perkins
It's one thing surviving in the concrete jungle but making it in the wilderness is a real test of endurance, as Ceri found out when she chatted to an SAS expert on page 12.



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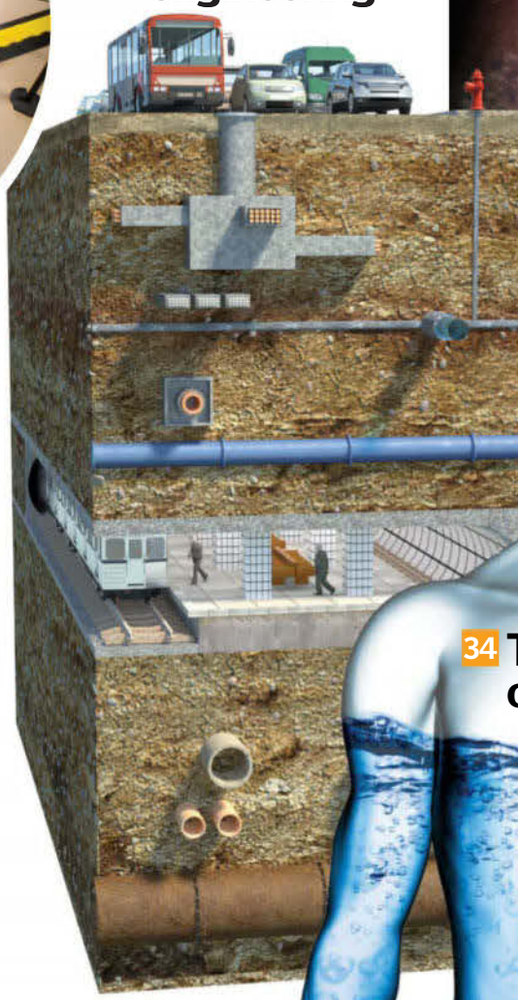

SUBSCRIBE NOW!
Go to page 90 for great deals

New York to London in three hours

The supersonic windowless jet that can cut long-haul journey times in half

Fancy flying from London to Dubai and being back in time for dinner? That's what the Spike S-512 supersonic jet can achieve. The private aircraft can carry you and 17 other passengers at up to 1.8 times the speed of sound, double the maximum speed of a Boeing 747, making day trips to faraway countries possible. The first S-512 concept was unveiled in 2013, but new updates to its design have improved its performance. For example, the wings and tail have been modified to reduce drag, making it faster and more fuel-efficient. It's expected to take-off in 2018, but it would be a good idea to start saving now as it's estimated to cost between £38 million and £52 million ($60 million and $80 million) to own one.

Virtual windows

Supersonic speed is not the only impressive thing about the Spike S-512. The luxury 'Multiplex Cabin' will enable you to travel in complete comfort, with soft leather seats, increased oxygen levels and reduced cabin noise. To make the aircraft even lighter and create a smoother exterior to minimise drag, the windows have been replaced by large screens displaying panoramic views of the outside world captured by cameras surrounding the aircraft. However, if you don't want to admire the view, the screens can also be used to display movies or business presentations thanks to the high-speed wireless internet access on board.

Legroom isn't an issue in the Spike S-512's spacious cabin

The S-512 has a maximum speed of Mach 1.8 (2,205 kmh/1,370 mph)

©Spike Aerospace, Inc.

The satellite can send back images just 12 to 36 hours after they were taken

DSCOVR can monitor solar winds, which disrupt power grids, GPS and telecommunications

The EPIC blue marble

Satellite photographs show our planet from 1.6 million kilometres away

NASA's Deep Space Climate Observatory (DSCOVR) satellite has sent back its first view of the entire sunlit side of Earth. The photo is a combination of three different images taken using DSCOVR's Earth Polychromatic Imaging Camera (EPIC), a 4-megapixel CCD camera and telescope. The blue tint of the photo comes from the way the Earth's atmosphere scatters sunlight, but the team running EPIC are working to remove this effect from future images to show the planet's true colours. DSCOVR will soon begin sending back daily snapshots of Earth, enabling scientists to collect a variety of data about our planet, such as atmospheric aerosol and ozone levels, ultraviolet reflectivity and cloud height

© Tara Oceans

The sleek Blade weighs just 635 kilograms (1,400 pounds)

World's first 3D-printed supercar

The lightweight Blade can be assembled like Lego

Starting off as a pile of 3D-printed aluminium joints and carbon fibre tubing, the Blade supercar's chassis can be slotted together in a matter of minutes. It also weighs 90 per cent less than a traditional car chassis, despite being stronger and more durable. The company behind the car, Divergent Microfactories, says this new approach to manufacturing is more environmentally friendly as it produces much less pollution. The car itself can be powered by compressed natural gas or gasoline, and go from zero to 97 kilometres (60 miles) per hour in just 2.2 seconds.

The PlasticRoad project is still in the early stages, but trials should take place in the next few years

Building plastic roads

Future roads could be quieter, heated and generate power

The Dutch city of Rotterdam could be the first to build roads made of recycled plastic. The material has several benefits over asphalt as it is more lightweight and would take less time to install. The roads would also be able to withstand corrosion and extreme temperatures, tripling their lifespan and reducing the need for maintenance. The structures can be hollow to run cables and pipes though them and could even be adapted to make them quieter, heated and able to generate electricity from the kinetic energy of the cars that use them.

GLOBAL EYE

10 COOL THINGS WE LEARNED THIS MONTH

Honeybees could replace sniffer dogs

Now that cannabis has become legal in certain parts of America, some sniffer dogs have become less effective in finding other drugs as they remain trained to alert their handlers to the presence of the substance. A German study has found that honeybees are good at detecting heroin and cocaine, and that it's possible to train them to fly away when they detect these drugs. This offers a cheaper and more effective alternative, and they might even be used to detect explosives and disease.

A camera ball helps police in danger

This tactical camera ball can be used during raids or arrests to gain a tactical advantage, helping police see and evaluate the situation they are about to enter. It captures several photos per second, creating a 360-degree image that's relayed to the user's screen.

Neanderthals and modern humans interbred in Europe

Through the analysis of 40,000-year-old DNA, scientists have shown that early Homo sapiens in Europe interbred with Neanderthals. Scientists analysed genetic material extracted from a jawbone, found in 2002 in Romania, and discovered that this ancient human was more closely related to the Neanderthals than any other they'd examined before, potentially having a Neanderthal ancestor only four generations back in its history.

Sweat-eating bacteria make feet smell

The bacteria that thrive on our feet produce an acid by-product when they consume our sweat. The fact that they're eating our sweat is actually a bad thing when it comes to smell. Sweat itself is odourless, it's the acid that these bacteria produce that creates the strong odour.

Toddlers know right from wrong

A recent study has shown that toddlers have a strong sense of justice, with children as young as three wanting to return stolen biscuits to their rightful owners. Well-known for their tantrums, this innate sense to do the right thing has never been observed before in toddlers, with many researchers presuming that this type of behaviour was learned from others.

There's a bulletproof briefcase

The Multi-Threat Shield appears to be a normal briefcase, but can actually be used to carry a firearm, taser and medical supplies. Its most extravagant feature is a unique panel that opens up to reveal a 0.9-metre (three-foot) long shield, capable of stopping most bullets fired from a handgun. Made from ballistic nylon and laminated Kevlar, this is surely the toughest briefcase on the market.

Global warming makes flight times longer

Research suggests that global warming may actually exacerbate its own causes, due to the effect it has on passenger jets. Global warming produces stronger high altitude winds, which increase flight times as planes have to battle tougher conditions. It's estimated that some flights take a staggering 11 minutes longer due to this. If, for example, every long-haul flight were to take just one minute longer, this would result in 300,000 extra flying hours every year. Due to this, both costs and carbon dioxide admissions are increased, which is bad news for everyone.

A smart bikini can prevent sunburn

Working in conjunction with your smartphone, the smart bikini alerts the wearer when they need to apply more sunscreen or have been exposed to too much UV, based on their individual skin type. It comes fitted with a UV sensor no bigger than the size of a small buckle, and helps the wearer enjoy the sunshine without getting burnt.

NASA spotted 'Lord of the Rings' in Milky Way

With the help of NASA's Chandra Observatory, astronomers have discovered the largest and brightest set of rings from X-Ray light echoes that have ever been observed. These circular rings are produced by an intense burst of X-rays from a neutron star, located around Circinus X-1, a double star system. This neutron star is the remains of a massive star destroyed by a supernova explosion.

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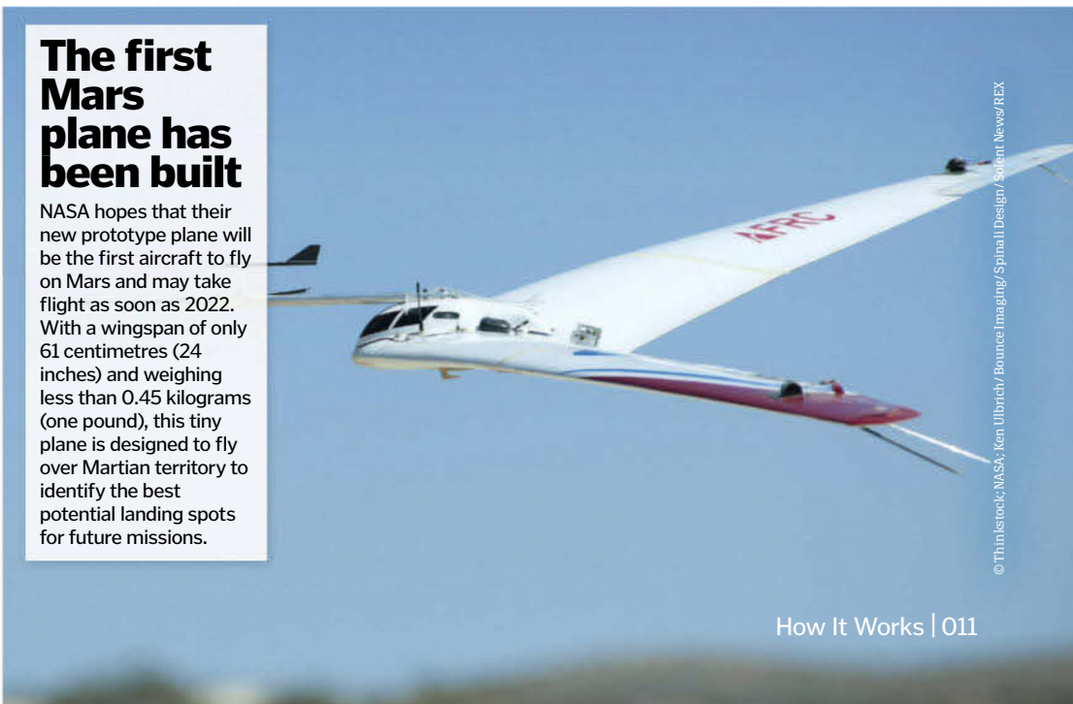
The first Mars plane has been built

NASA hopes that their new prototype plane will be the first aircraft to fly on Mars and may take flight as soon as 2022. With a wingspan of only 61 centimetres (24 inches) and weighing less than 0.45 kilograms (one pound), this tiny plane is designed to fly over Martian territory to identify the best potential landing spots for future missions.



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YOUR GUIDE TO SURVIVAL

SAS VETERAN JOHN WISEMAN REVEALS HOW TO TAKE ON THE WILDERNESS AND WIN

Being stranded in the wilderness might look exhilarating when it's Tom Hanks or Evangeline Lilly living it on the big screen, but in reality it is stressful stuff. Even if you never set foot on a plane, you run the risk of getting stranded whenever you venture far into the great outdoors. You might lose your way in foul weather; you might slip and fall; you might ski down the wrong side of the mountain as the Sun is setting.

Whatever the scenario, basic skills like being able to build a shelter, light a fire and identify safe food and water, could mean the difference between life and death.

According to John 'Lofty' Wiseman, author of the *SAS Survival Handbook*, your first priority is to analyse your surroundings and make sure it's safe to stay put. Are you in the path of an avalanche or forest fire? Are there predators nearby? Is there a chance that your crashed plane's fuel tank might explode?

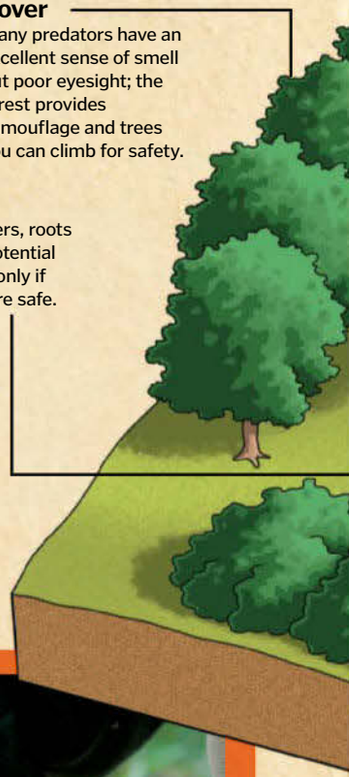
"You should always stay where the incident is, as long as it's safe to do so," Lofty explains. In the case of a downed plane, you might be able to utilise parts of the wreckage, and it's by far the easiest ground signature for rescuers to spot from the air.

Lofty served in Britain's elite Special Air Service (SAS) for 26 years and is a globally recognised authority on all things survival. To work out what to do and when to do it, he advises using the acronym PLAN. "It's a sequence you can go through anywhere – in the Arctic, the desert, the jungle and even at sea."

P is for protection: from the elements and from immediate dangers. The biggest cause of death in survival situations is hypothermia, but in the desert, Sun exposure can be just as serious. Your first port of call should be to build yourself a shelter.

I is for location and reminds you to immediately set up ways to signal your distress to potential rescuers. A is for acquisition – of food and water. In extreme conditions, the human body can survive three days without water and three weeks without food, but only three hours without protection in the worst weather. Don't make the mistake of looking for water before you've built your shelter.

Finally, N is for navigation. Your best chance of rescue is almost always to stay put, but eventually you may have to accept that no help is coming. Robust natural navigation skills will be your only guide as you attempt to make your way to safety. Over the next few pages, arm yourself with the essential skills to stay alive.



Cover
Many predators have an excellent sense of smell but poor eyesight; the forest provides camouflage and trees you can climb for safety.

Edible plants
Leaves, fruits, flowers, roots and stems are all potential food sources – but only if you're certain they're safe.

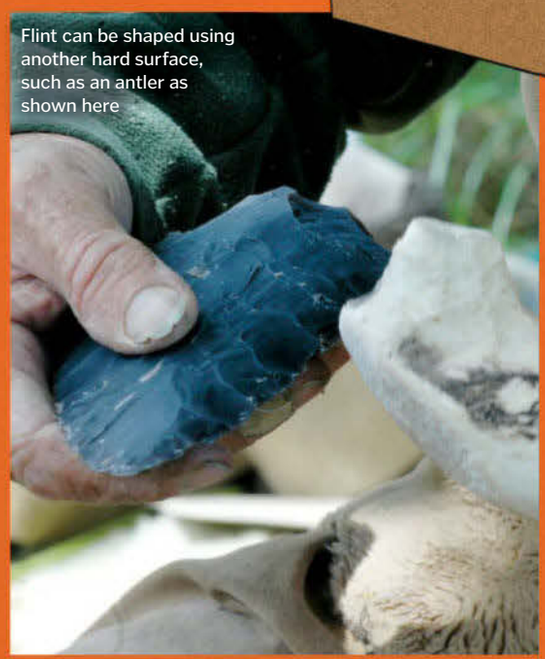
TOOLING UP

If you're stuck without basic survival tools, all is not lost. With a bit of creativity and patience, you can improvise some key items that will help you get by.

First thing's first: you need to get in touch with your inner caveman. Before humans learned to mine and meld metals, we fashioned tools from stone, bone and other items we could find.

You can create a blade by splitting a stone with a hard blow from another stone, then chipping further segments away to refine the edge. This can be used as a knife, or lashed to a stick – with vines or dried sinews recovered from animal carcasses – to create an axe.

Once you have a cutting blade, you can put springy saplings to a multitude of uses – anything from snowshoes to a bow to shoot self-made arrows. Sharpened antlers and bones become perfect fishing spears, while small, sharp fish bones make excellent sewing needles.



Flint can be shaped using another hard surface, such as an antler as shown here

SIZE UP YOUR SURROUNDINGS

High ground
If you are able to easily climb to higher ground without endangering yourself, analysing your wider surroundings from above may help you navigate a path to safety.

Open areas
Rescue planes are more likely to see signal fires in open locations that aren't sheltered by surrounding ridges.

Forest
Fallen trees, branches and leaves can be burned for warmth, signalling, cooking and sterilising water; the canopy offers shelter in bad weather.

Fresh water
Lush vegetation indicates springs and streams. Look for flowing water rather than stagnant pools, although either will do in an emergency.

Camp
Build your shelter away from water on level ground. Organise your supplies and light a fire at a safe distance from your shelter.

Backpack
Check your possessions for useful items like matches, string, cloth, or a penknife – use your imagination in repurposing everyday items.

A shelter will provide vital protection from the elements

Shoreline
By the sea you will have access to salt water for rinsing and cleansing, and are likely to find fish and seaweed for food.

Finding a fresh water source should be one of your top priorities

Illustrations by Tom Conell/Art Agency

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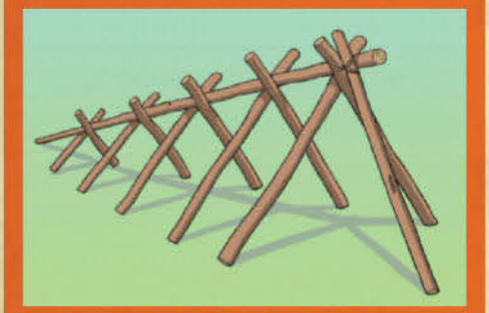
HOW TO MAKE YOUR OWN SHELTER

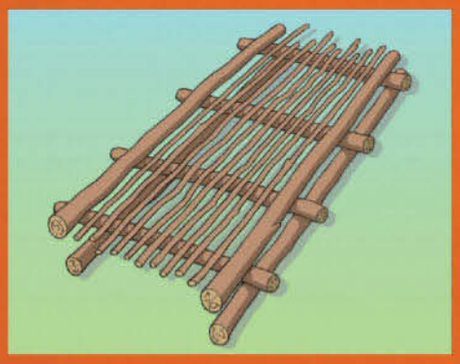
Poncho shelter

When time is short or weather is bad, this kind of shelter can be erected quickly with just two basic materials: a waterproof poncho or groundsheet and a length of rope. Spare plastic sheeting can be curled underneath the inhabitants, running downhill so that it keeps out surface water.



Lean-to shelter

If you don't have any rope, a lean-to shelter is your best bet. Its central beam should be either a low branch attached to a tree, or a long straight branch propped up at one end in the fork of a second, Y-shaped branch. The low end of the central beam should face into the wind.



Bed frame

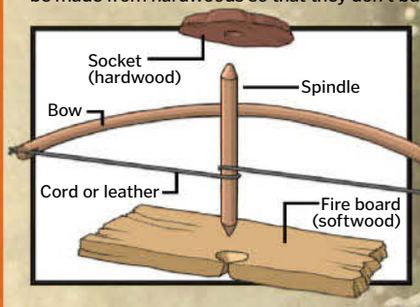
Sleeping on cold or damp ground causes you to lose essential body heat. A raised bed frame enables an insulating layer of air to circulate underneath you, as well as putting some distance between you and the creepy crawlies! The basic platform can be padded with leaves or soft pine boughs for a more comfortable night's rest.

BUILD A FIRE

How to make a fire using the bow and drill technique

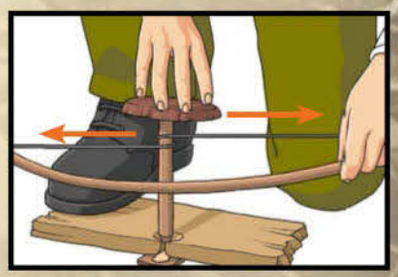
1 Build your apparatus

Construct a bow from a curved green branch and a length of cord such as a bootlace. For the spindle, you'll need a smooth, straight stick with a sharpened point. The spindle and socket should be made from hardwoods so that they don't burn.



2 Create friction

Taking a flat piece of softwood, cut a notch at its centre edge so that it almost penetrates the underside of the board. Using the block to hold the spindle in place, move the bow back and forth to make it spin.



3 Pad the ember

The heat created by the bowing action will create a pile of hot, black ash under the notch. Lift away the fireboard to allow this ash coalesce into an ember. When it begins to glow, pad the ember in tinder (dry material).

4 Ignite

Blow gently on the tinder-wrapped ember until it bursts into flames. Place it in a fire pit and add kindling to encourage the fire to catch. Gradually add larger sticks and logs until you have a robust fire.

FINDING FRESH WATER

How to stay hydrated when you're stranded in the wilderness

The human body contains around 40 litres (10.6 gallons) of water, but we lose 2-2.5 litres (0.5-0.7 gallons) every 24 hours through basic processes like breathing, digestion, temperature regulation and waste elimination. If this water isn't replaced, we quickly become dehydrated and will die within days. Finding reliable sources should be high on the survivor's list of priorities.

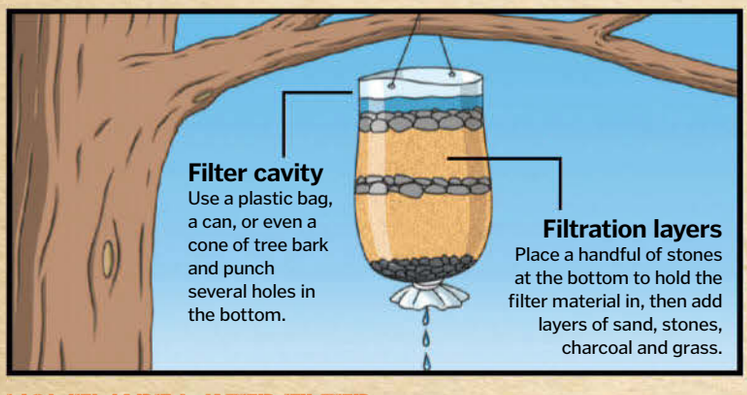
Water runs downwards, so avoid high ground and head for valleys. You can spot concealed rivers and streams from a distance by the lush vegetation that crowds the edges. Plants aren't the only clues, explains Lofty: "The grain-eating birds must have water, so by watching them you have a good indication that there's water within a mile." This might not be obvious – it could be pooled high in the fork of a tree, for example – so keep your wits about you.

There are several ways of collecting water and setting up more than one system will increase your chances of survival. With the exception of fresh rainwater that you've collected yourself, assume that none of the water you find is safe to drink. Even clean-looking river water could be full of harmful bacteria from decomposing animal carcasses further upstream.

"In a survival situation, 90 per cent of all ailments are caused by drinking bad water," says Lofty. Make sure you boil yours or treat it with chemical sterilisation tablets.

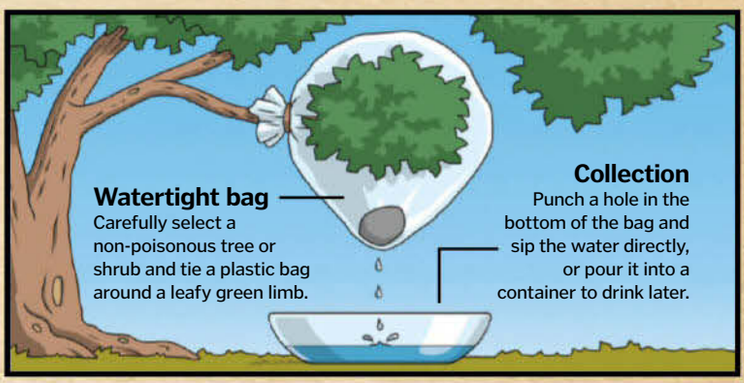
Never drink seawater as the salt content will make you vomit and dehydrate your body further. If you have the apparatus, you can distil it to make it safe. Similarly, you should melt snow and ice before consuming it; eating the cold stuff can actually cause dehydration because of the energy your body uses to melt it.

Even fresh water can contain bacteria, so where possible you should sterilise it before drinking



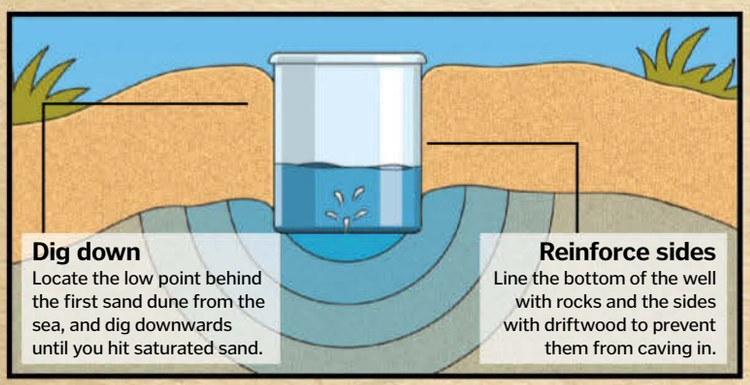
HOMEMADE WATER FILTER

Water collected from streams or the ground should be filtered to remove debris and chemical impurities. The more layers you can put in your filter, the better, but remember – filtered water could still contain harmful bacteria, so distil or boil it before drinking.



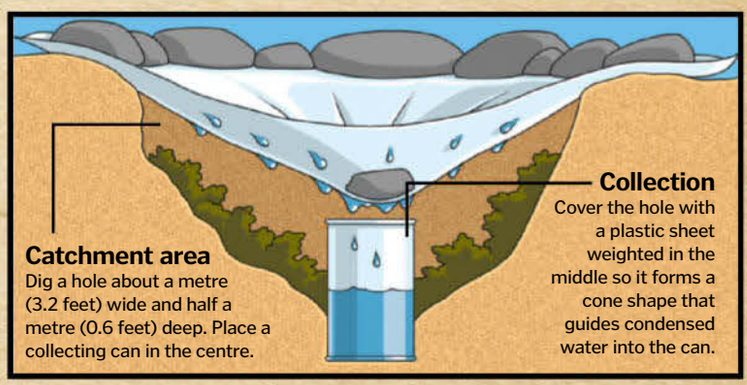
TRANSPIRATION BAG

Wherever vegetation grows, you can be sure that there is a good supply of water deep underground. Think of a tree as a leisurely tap, pumping water to the surface and into its leaves. You can collect this water as it evaporates from the leaves' surface.



BEACH WELL

You might assume that all seawater would be too salty to drink. But in fact sand is a natural filter, capable of desalinating seawater just 30 metres (100 feet) or so from the shore. You can tap into drinkable water by the coast by building a beach well.



SOLAR STILL

You can draw moisture – in the form of water vapour – out of soil, sand and cut vegetation, by digging a hole in a sunny spot and covering it with a plastic sheet. As the hole heats up and the air becomes saturated, the vapour will condense on the underside of the sheet.

© Thinkstock; CG Textures

FIRST AID IN THE WILDERNESS

How to tend to your health many miles from modern medicine


A small injury can quickly become serious if left untreated

Maintaining good health is imperative for survivors. Far from the security of hospitals and trained doctors, minor injuries can become major issues. Never take unnecessary risks that could leave you injured. Make prevention your top priority by paying close attention to any signs of distress that your body sends you.

Even a seemingly simple ailment like a blister can deteriorate if you don't take steps to keep on top of it. "If it festers, it can become a major obstacle, especially in a survival situation when you have limited resources," says Lofty. "It leads to septicaemia and can even be life threatening."

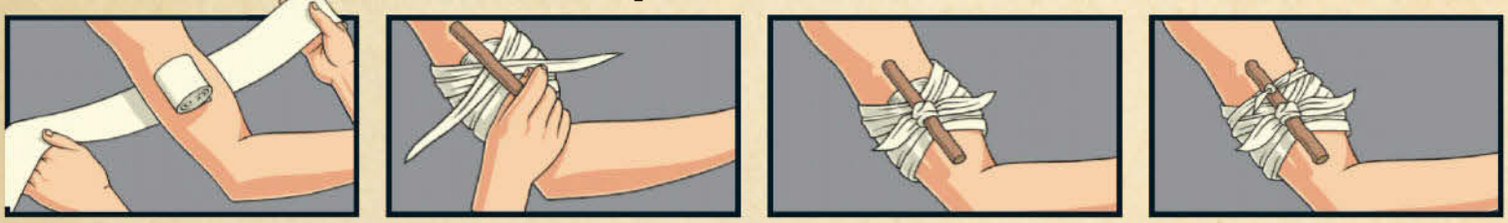
Look after your basic needs by trying to eat a varied diet, getting adequate rest and fluids, and keeping your camp area clean. Learn to recognise the early signs of dehydration, food poisoning, shock and infection. Brush up on your emergency first aid skills now. In the wilderness you become your own doctor, so the wider your medical knowledge, the better.

The same goes for understanding medicinal plants. "The majority of our medicines come from plants," says Lofty. "It's a very specialist subject but the more you know about it, the better you're able to cope with an emergency."

For example, willow contains salicin, an anti-inflammatory agent from which the active ingredient in aspirin is derived. You can crush and boil a handful of bark and leaves to make a tisane (a herbal tea) to treat pain or discomfort. Bracken is poisonous, but an infusion of its roots rids sufferers of worm infestations; burdock root is used to clean wounds; witch hazel leaves can soothe bites; thyme has antiseptic properties.

Finally, you mustn't underestimate the importance of morale. A sick person who retains the will to live stands a much, much higher chance of survival.

How to fashion and tie a tourniquet



1 Prepare site
A tourniquet can be applied in an emergency to the upper arm or thigh. Find a long scrap of cloth at least five centimetres (two inches) wide – thinner could damage the flesh – and place it above the injury site.

2 Wrap
Put a pad of fabric under the tourniquet to stop the skin from being pinched. Wrap the strip of cloth around the limb three times, then tye a half-knot. Place a long stick on top of the half-knot.

3 Twist
Tie a double knot over the stick to secure it. Twist the stick to tighten the band until the blood stops flowing beyond it. Ensure it's tight enough to stop blood in both the veins and the deep arteries.

4 Secure and monitor
Secure the opposite end of the stick with another piece of cloth. Monitor the injured person for blue, cold or numb fingers or toes. Relax and re-tighten the tourniquet frequently to let blood reach the tissues.

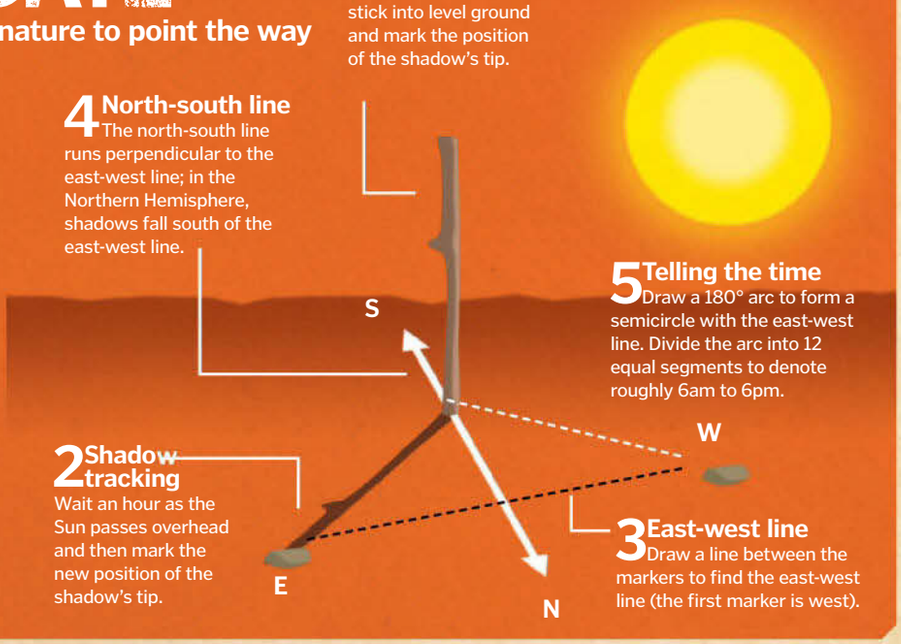
HOW TO NAVIGATE

Learn to read your surroundings and allow nature to point the way

The Moon and stars are the most well known tools in the natural navigator's toolbox. On nights with a high crescent Moon, you can get rough bearings by imagining a line connecting the crescent's two tips. Where this line meets the horizon is approximately south. When the Moon rises before sunset, its western side is brightest; when it rises after midnight the eastern side shines brighter.

Polaris – the North Star – is the only star that remains stationary in the Northern Hemisphere's night sky. You can spot it by locating the Plough constellation and looking off in the direction that its last two stars (in the 'bowl' of the saucepan) point. The bright star a short distance away is Polaris, and it hovers right over the North Pole.

Plants and animals also offer navigation hints to attentive wanderers. For example, in the Northern Hemisphere, the Sun shines mostly from the south. Because of this, trees tend to be bushier on their south sides and ants often build their nests on these warmer facades.



1 Shadow stick
Drive a long, straight stick into level ground and mark the position of the shadow's tip.

2 Shadow tracking
Wait an hour as the Sun passes overhead and then mark the new position of the shadow's tip.

3 East-west line
Draw a line between the markers to find the east-west line (the first marker is west).

4 North-south line
The north-south line runs perpendicular to the east-west line; in the Northern Hemisphere, shadows fall south of the east-west line.

5 Telling the time
Draw a 180° arc to form a semicircle with the east-west line. Divide the arc into 12 equal segments to denote roughly 6am to 6pm.

FINDING FOOD

What to eat in the wild, and where to find it

If you're stranded in the wilderness with few or no provisions, it won't be long before maddening hunger dominates your thoughts. But with a bit of knowledge, ingenuity, and a willingness to overcome food prejudices, you can tap into nature's bounty and feed yourself in almost any situation.

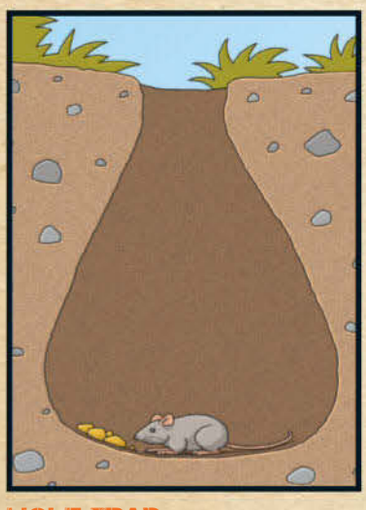
To meet your body's basic nutritional needs, aim to eat a range of different foods. Winter hunters with nothing but supplies of rabbit have died from acute malnutrition – a phenomenon known as 'rabbit starvation' – because the lean meat lacks sufficient carbohydrate and fat.

Plants are an excellent source of carbohydrates, vitamins and minerals. Starchy roots are especially energy dense and in summer, fruits and berries are plentiful. But beware – many are poisonous! The universal edibility test is a series of checks that you can perform to ascertain which parts of plants are safe to eat.

Unfortunately, the test won't work for fungi, meats or fish. With these, only ever eat things you can positively identify. To get your protein fix, use a length of wire to snare small mammals. Look for fish in shallow waters and if you catch one, salvage the contents of its guts to use as bait to catch more.

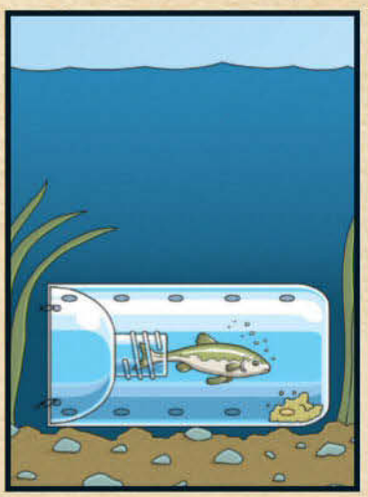
With flesh it must be fresh, so trust what your nose tells you. Cook all meat and fish to rid it of bacteria and parasites. "You'd be surprised what you can get away with if you boil it," says Lofty.

Finally, the sooner you can overcome squeamishness, the better. Get used to the idea that the most accessible and nutritious food – that means insects and grubs – will likely be a lot different to what you are used to eating. Just make sure you steer clear of the brightly coloured ones.



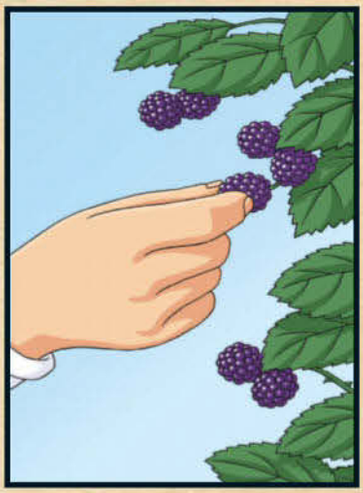
HOLE TRAP

To catch small rodents, dig a narrow and deep hole. Carefully extend the deeper portion of the hollow sideways, scooping out the earth through the narrow opening. Rest a handful of sticks over the hole, propped up on small stones. Mice that are seeking shelter will fall into the hole and be unable to escape.



BOTTLE TRAP

An empty plastic bottle is easily repurposed into a trap to catch small fish. Cut off the top portion of the bottle just below the neck and place it inside the bottom portion, with the neck facing towards the base. If you bait the trap, dinner will swim right in, but struggle to find its way out again.



BERRY PICKING

You should never eat a berry you can't confidently identify, but in an emergency, use the universal edibility test. As a rule, stick to the darkest fruits – 90 per cent of blue, black, and purple berries are edible, compared to only 50 per cent of red berries and less than 10 per cent of green, white and yellow berries.

HOW TO PERFORM THE UNIVERSAL EDIBILITY TEST

- Crush a small piece of the plant to express the juice. If it smells funky, discard it.
- Touch it to your wrist and wait ten minutes to see if your skin reacts to the juice. If it does, then get rid of it.
- Rub a crushed piece on your lower lip and wait another ten minutes. If it starts to sting or burn, throw it away.
- Place the piece inside your lip and wait anther ten minutes. If it tastes sharp, soapy, or it stings, discard it.
- Finally, swallow a small piece and spend at least five hours watching out for adverse effects, before deeming that part of the plant safe to eat.

A GUIDE TO DANGEROUS FOOD

Death Cap
The clue is in the name. It is one of the deadliest fungi around, so make sure you steer clear!

Horse chestnut
Unlike edible sweet chestnuts – whose husks have finer, hairier spines – these are poisonous.

Deadly nightshade
Easily mistaken for blueberries. Can cause hallucinations and death.

Mussels
In tropical zones, mussels are highly poisonous if consumed during the summer months.

Cassava
These fat tubers are lethally poisonous raw, but nutritious when cooked through properly.

Rhubarb leaves
By all means stew the stalks for a delicious dessert, but avoid the toxic leaves.

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ESCAPING THE WILDERNESS

How to signal for help and strike out for civilisation

To give yourself the best chance of making it out of your ordeal alive, your primary tactic should be to stay put and draw as much attention to yourself as possible. If you have access to flares or a satellite phone, use them sensibly – they (or their batteries) won't last forever. Write SOS – for Save Our Souls – on the ground as large as you can with contrasting materials that won't wash away.

Three fires is an internationally recognised distress signal. Ideally, they should be laid in a triangular formation, equidistant from one another. Failing that, a straight line or any other prominent configuration will do. Build them on open ground where they will be clearly visible from the air.

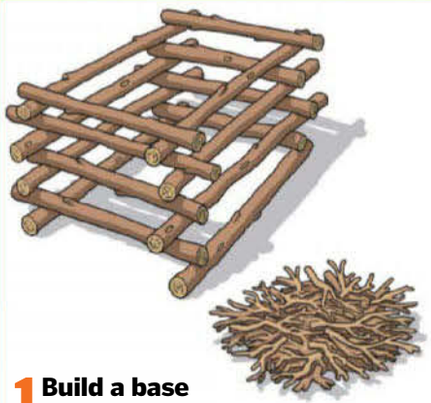
Be aware that different materials produce different kinds of smoke, and you should aim to produce signals with the greatest contrast to the rest of the ground. Green boughs produce white smoke that stands out against the dark forest. Oil and rubber produce black smoke that contrasts well with sand.

Almost any signal repeated six times will be recognised as a distress signal. You could use a mirror to flash sunlight at passing aircraft or an emergency whistle to alert other people who could be on the ground nearby. Leave a minute between each set of six signals.

Eventually, if it seems that rescue is unlikely, it will be up to you to attempt the journey back to civilisation unaided. Following the coast or riverbanks can often be easier than going through forest. Leave clear markers behind you as you go, so that searchers can see the route you have taken.

HOW TO BUILD A SIGNAL FIRE

Flames and smoke are ideal for drawing attention to yourself and your plight



1 Build a base

Build a raised platform to keep tinder off potentially wet ground. Load the platform up with dry leaves, twigs and kindling so that the fire will get going quickly and burn fast if you have to light it at a moment's notice.

2 Load up the smoke stock

Cover the base with grass, leaves, moss, ferns and evergreen boughs. This material produces billows of thick white smoke when it burns, and it will also help to keep the inner core of kindling dry if it rains.

3 Signal

If you have a signal flare and see an aircraft nearby, strap the flare to the end of a long pole and hold it in the fire's rising smoke. The flare colour will be carried up with it, improving the visibility of your signal.

SURVIVAL ESSENTIALS

Packing these vital items will dramatically boost your chances in a survival situation

Plastic bottle
Having a plastic bottle enables you to store and carry water, which may be crucial if you travel to hot areas where drinkable water is difficult to source.

Rope
Not only good for navigating steep terrain, rope can help you build a shelter or a raft and can even be used as a fishing line.

Duct tape
Duct tape has various uses, from repairing damaged clothing or shelters to affixing bandages or slings.

Hunting knife
A good hunting knife will be both sharp and robust. Ideally, it should be kept as clean as possible so that it can be used to prepare food.

Torch
Torches are useful for navigation and shelter building. An LED torch rather than a traditional bulb torch is recommended.

Steel beaker
A steel beaker is easy to clean and will heat its contents quickly, enabling you to cook food or sterilise water fast. A stand for the beaker is useful, as it helps to keep it level when cooking over a fire.

Matches
Keeping matches in a waterproof container will ensure that they're easy to light when you need them.

Saw
Carrying a saw is vital if you plan on building a shelter as it can cut through wood easily compared to a hunting knife. Many are designed with a retractable blade, helping ensure it remains sharp and damage free.

Compass
Knowing where you are and what direction you're heading is key which is why a compass should be one of the first items you pack.

Axe
A felling axe is lightweight and sports a thin blade which makes it perfect for chopping into trees to provide fire wood.

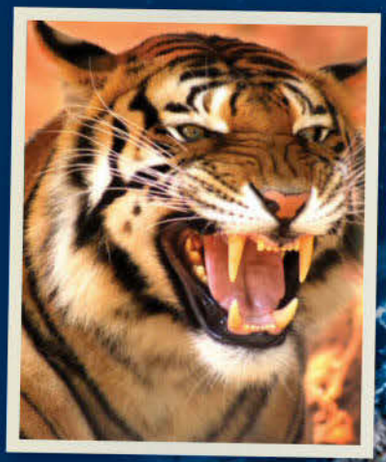
ULTIMATE SURVIVAL KIT

Two things that will be invaluble in the wild

Satellite phone
Your swiftest route to rescue is to communicate your location and circumstances to the outside world. Satellite phones work virtually anywhere in the world, including in remote areas and during violent storms.

First Aid kit
In the wilderness, minor injuries and infections can quickly become life threatening if left untreated. Your kit should include plasters and bandages, painkillers, diarrhoea medication, malaria tablets, antiseptic and antihistamines to quell insect bites and stings.

© Thinkstock; Dreamstime; CG Textures



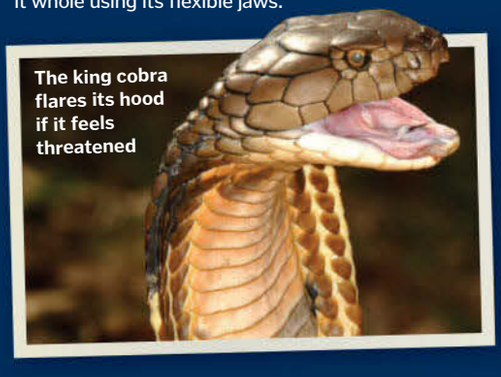
THE WORLD'S DEADLIEST PREDATORS

SNAKES

Discover how lethal one of the world's most terrifying creatures actually is

THE KING COBRA

The king cobra can reach 5.5 metres (18 feet) in length, making it the longest venomous snake in the world. With their trademark hood flaring, they emit a hair-raising hiss before delivering up to seven millilitres (0.25 fluid ounces) of venom in one bite. King cobras strike aggressively in self-defence, stabbing with unrivalled agility and precision. They can detect movement 91 metres (330 feet) away. Then, once the prey is dead, the king cobra swallows it whole using its flexible jaws.



The king cobra flares its hood if it feels threatened

BURMESE PYTHON

The Burmese python is one of the largest snakes in the world; an adult weighs around 90 kilograms (198 pounds) and can be up to seven metres (23 feet) long. Despite being native to Southeast Asia, they have begun to dominate the Florida Everglades national park after a few were introduced. On the menu are birds, mammals and reptiles, and prey is located using chemical receptors in the tongue and heat sensors in the jaw. The python then uses constriction to squeeze the victim to death with its body.

THE BLACK MAMBA

Two drops of black mamba venom will shut down a person's nervous system and kill them. This is a common problem in Africa – their native habitat – where thousands of people die from snakebites each year. The black mamba is also the fastest land snake in the world. They are capable of moving at 20 kilometres (12.4 miles) per hour, enabling them to easily evade predators. Black mambas hunt from lairs, launching attacks from a hidden location. Once they've bitten, they release the prey and wait for the venom to take hold.

CROCODILE VS. ALLIGATOR

See how the most aggressive crocodile compares to America's mammoth alligator

Comfortably the world's largest reptile, the saltwater crocodile is an extremely successful predator. Equipped with bony armour, beefy muscularity and a lethal bite force, they are able to overwhelm even the largest prey that live in their ecosystem. Most of their hunting is done during the evening and at night, when they will wait partially submerged before ambushing their prey. Once their prey is within reach, saltwater crocodiles strike without warning. Small prey can be swallowed whole, but larger creatures are first incapacitated by a death roll – the crocodile bites down hard on its prey before flipping into the water. This technique is repeated once the victim has drowned to tear it into manageable chunks.

Once considered an endangered species, the American alligator is now thriving. They are stealthy predators and often float along the water, camouflaged as a drifting lump of wood. Like the saltwater crocodile, these gators are immensely powerful – their strong jaws can crack through a turtle's shell – and they will eat almost anything, including a human, if they are hungry enough.

SALTWATER CROCODILE

Average size: 5M (16.4FT)

Lifespan: 70 YEARS

Weight: UP TO 1,000KG (2,205LB)

Population: 200,000-300,000

Teeth: 60+

Saltwater crocodiles have been known to tackle other apex predators, such as bull sharks

AMERICAN ALLIGATOR

Lifespan: 35-50 YEARS

Average size: 4M (13FT)

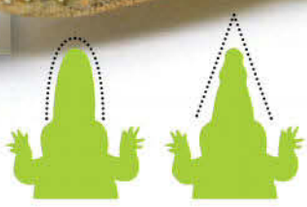
Teeth: 74-80

Weight: UP TO 460KG (1,012LB)

Population: OVER 1 MILLION

Alligators are capable of short bursts of speed, leaping out of the water quick enough to catch prey unawares

The crocodile has a more distinctive V-shape snout, whereas the alligator has more of a U-shape. The crocodile's shape is optimised for snatching their prey, while the alligator's is better for crushing, as it has more leverage.



The jaws of these two behemoths differ greatly. The top of an alligator's jaw is wider than the lower part and has slots for the lower teeth to fit into, so only the upper teeth are visible when closed. Conversely, a crocodile's jaws are identical in size. Its teeth interlock, so both upper and lower teeth can be seen.

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POLAR VS. GRIZZLY BEAR

Is the king of the Arctic more deadly than the mighty grizzly?

The polar bear has no equal in the Arctic, roaming fearlessly in its hunt for food. There is no tougher environment to thrive in and life can be challenging when trying to meet insatiable hunger. The polar bear's favourite snack is a ringed seal which is packed full of energy-rich blubber that is key to their survival. They hunt with a variety of techniques, from sneakily swimming up to their prey, to waiting at seal breathing holes in the ice.

Like the polar bear, the grizzly tends to live in solitude; it has no need to form packs or clans due to its ferocious defensive capabilities. They eat lots of nuts and berries, but can take down large animals with their immense strength. Dramatic gatherings of grizzlies are rarely seen, but you can guarantee to spot them when the salmon begin to swim upstream before spawning in the summer months. This chance to feast on valuable fat and vitamins is too good to miss, and will help sustain them for the coming winter months.

	Polar bear	Grizzly bear
Maximum weight	1,000KG (2,205LB)	400KG+ (882LB)
Shoulder height	1.6M (5.2FT)	1.1M (3.5FT)
Average lifespan	15-18 YEARS	20-25 YEARS
Maximum running speed	40KM/H (25MPH)	56.3KM/H (35MPH)
Paw size	30CM (12IN) WIDE WITH 5 CLAWS	20-25CM (8-10IN) WIDE WITH 5 CLAWS

Streamlined form

Polar bears are adapted to their marine lifestyle. They have longer necks and narrower skulls than grizzly bears, creating an overall streamlined shape that enables efficient swimming.

Shoulder hump

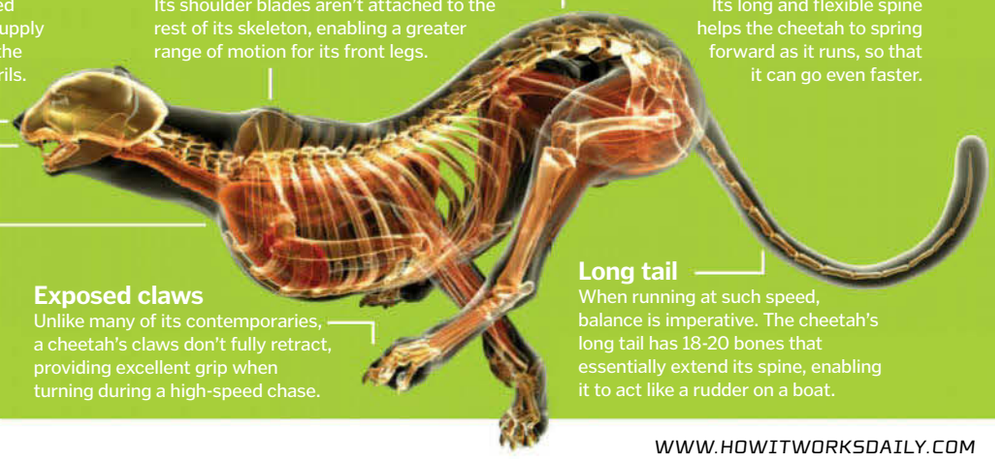
Grizzlys have a distinctive shoulder hump made of strong muscle that enables them to be powerful diggers. Polar bears are also known to dig snow dens, but don't have humps.

Claw comparison

Grizzly bears have much longer claws than their Arctic counterparts. Comparable to the length of a human finger, they use their claws to dig dens, root out vegetation and swipe at salmon.

DESIGNED FOR SPEED: THE CHEETAH

See how a cheetah's anatomy contributes to its undisputed title of fastest land animal



Oxygen supply

Running at high speed requires a plentiful supply of oxygen, aided by the cheetah's large nostrils.

Free-floating shoulder blades

Its shoulder blades aren't attached to the rest of its skeleton, enabling a greater range of motion for its front legs.

Flexible spine

Its long and flexible spine helps the cheetah to spring forward as it runs, so that it can go even faster.

Designed for speed

A cheetah's anatomy doesn't lend well to strength, instead it is completely focused on speed. This is seen by its relatively weak bite force and streamlined body shape.

Deep chest

The cheetah's deep and narrow chest helps it maximise lung capacity without compromising its highly aerodynamic shape.

Exposed claws

Unlike many of its contemporaries, a cheetah's claws don't fully retract, providing excellent grip when turning during a high-speed chase.

Long tail

When running at such speed, balance is imperative. The cheetah's long tail has 18-20 bones that essentially extend its spine, enabling it to act like a rudder on a boat.

BIG CAT DOMINATION

Dominating their food-chains, these big cats define apex predation

1 Black jaguar
Unlike many big cats jaguars love the water, often playing and hunting for fish in pools and streams. When on the ground, they kill their prey with one bone-crushing bite to the skull.

2 Eurasian lynx
Capable of killing prey three to four times its size, the Eurasian lynx is a solitary hunter that feasts on a range of mammals. It will usually approach by stealth, before pouncing on its victim.

3 The snow leopard
Capable of jumping as far as 15 metres (50 feet), this cat has remarkable physical strength. Their eyesight is six times better than a human's, and it uses its tail to keep warm and maintain balance.

4 Cheetah
The fastest animals on land, cheetahs usually hunt alone, catching smaller antelopes to feast on. Occasionally they work together to kill larger prey like wildebeest and zebras.

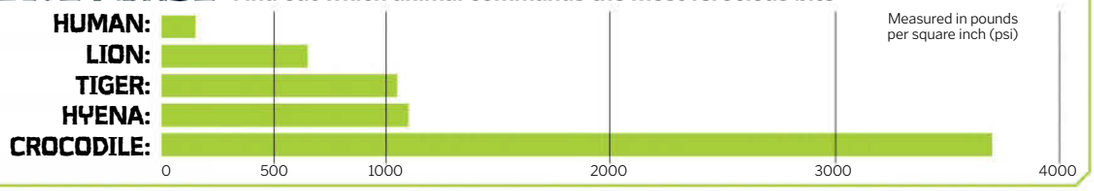
5 Lion
The male pictured would not do much hunting, as the lionesses are the ones that find food. They are equipped with vice-like jaws and lethally sharp claws to help them floor large mammals, such as zebra.

6 Tiger
As tigers live alone it's vital that they become accustomed to hunting. They sometimes hunt in the daytime but are proficient nocturnal hunters, due to their excellent vision.

7 Clouded leopard
Of all the big cats, the elusive clouded leopard owns the largest canine teeth relative to their size. They mainly hunt on the ground, feasting on deer, pigs and even monkeys!

8 Leopard
Leopards are excellent climbers which gives them the power to perform deadly ambushes from above. They pounce from tall trees to catch their prey by surprise and deliver a fatal bite.

BITE FORCE
Find out which animal commands the most ferocious bite



THE HYENA

This cunning creature really is no laughing matter

If it weren't for the mighty lion, hyenas would be the most successful predator in the whole of Africa. This might surprise some, as hyenas have a reputation for scavenging. However, the reality is that spotted hyenas kill up to 95 per cent of their own food. Living together in groups known as clans that can contain over 100 hyenas, they work together to hunt, defend territory and raise the clan's young.

Although some will hunt solo with relative success, hyenas prefer to operate in packs to divide and conquer their prey. Large groups can take down wildebeest and sometimes even buffalo, which both provide a more substantial meal for the clan. Unlike some of the big cats, hyenas are built for endurance; they don't need to use stealth or ambush tactics, as they are confident enough to tackle their prey head on. The pack identifies signs of weakness in the herd that it's attacking, and once they've chosen a target they chase at a speed of 60 kilometres (37 miles) per hour to catch their prey.

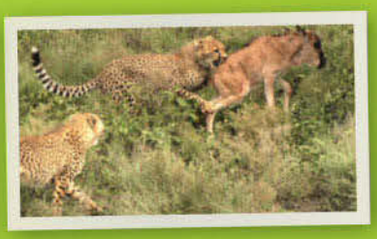
Hyenas kill by disembowelling as this is the quickest way and buys the clan precious time before lions or other competition arrive and try to scavenge their meal. They will share their kill dependent on each hyena's clan ranking, making sure that any high-ranking absentees still get their share of the meal. Incidentally, their famous maniacal laughs are thought to be an indicator of age or social status rather than good humour.

CHEETAH HUNTING TECHNIQUE

This cat keeps its eyes on the prize

STALK
A cheetah almost always approaches from behind, keeping hidden until it's 30m (98ft) from its prey. The animal's spots keep it concealed, as they break up the silhouette.

CHASE
Typically, a cheetah will select an isolated victim before launching an attack. It quickly accelerates to 113km/h (70mph), chasing its prey over hundreds of metres.



TAKEDOWN
The prey is knocked down to the floor when the cheetah reaches out with its front paw and swipes at the animal's hind legs. Then it goes in for the kill.

FEAST
Due to its weak bite, a cheetah uses a stranglehold to suffocate its prey by twisting beneath its victim and clamping down on the windpipe.

© DK Images; Thinkstock; Dreamstime

GREAT WHITE SHARK

Was *Jaws* right, or are killer whales the ocean's apex predator?

If you happened to be a creature on the great white shark's menu, then the proverb "out of sight, out of mind" wouldn't provide much comfort. Its super-sensitive snout is covered in sensory cells, enabling it to sniff out a seal colony from over three kilometres (two miles) away. Lurking below the surface to conceal its immense size – averaging 4.6 metres (15 feet) in length – the great white waits for an opening before torpedoing vertically through the water at fin-tastic speeds of up to 40 kilometres (25 miles) per hour.

They use their sharp teeth almost as disposable weapons; losing a few with every attack they perform. There are several rows of teeth behind the heavily-used front row, all ready and waiting to replace any that they lose. They can get through as many as 30,000-50,000 teeth in a lifetime!

The killer whale, however, is said to be more deadly than even the great white shark. They possess brainpower to match their brawn, with most scientists agreeing that these wondrous animals are capable of complex communication and even self-awareness. Their hunting techniques make the most of their intelligence and often involve ganging up on seals and knocking them off ice floes by creating a wave with their tails. They work together to prevent the seal from clambering aboard another ice block, creating underwater turbulence to disorientate it before eventually catching its prey and drowning it in the ocean's depths.

Maximum life expectancy
70 YEARS

Food consumed
30KG (66LB)
EVERY 12-15 DAYS

Maximum swimming speed
40KM/H (25MPH)

Number of teeth
300
IN MANY ROWS

CAN BITE WITH A FORCE OF UP TO 1.8TN

Length
4.6M (15FT)

Adult weight
UP TO
2,270KG (5,000LB)

BOX JELLYFISH

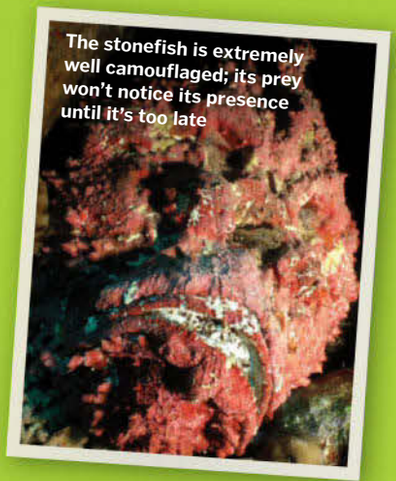
The box jellyfish has truly earned its nickname of 'sea wasp' and 'marine stinger'. Its venom attacks the heart, skin cells, and nervous system if you come into contact with it. Their main body, or bell, has four corners from which 15 tentacles can grow. These tentacles can reach three metres (ten feet) in length, and have 5,000 stinging cells each. It's a common misconception that these are triggered by touch; it is actually the presence of a chemical on their prey's outer layer that causes them to sting.

Unlike most of this species, box jellyfish can physically propel themselves, swimming at speeds of up to four knots (7.4km/h or 4.6mph).

These carnivorous jellyfish live for less than a year, and weigh up to 2kg (4.4lb)

STONEFISH

The stonefish is one of the most venomous fish known to man. It can mainly be found in Indo-Pacific waters, residing on the ocean floor near to tropical reefs. Stonefish are ambush predators, hunting their prey using surprise attacks when they swim past. They swallow their meals whole and the entire attack lasts around 0.015 seconds. The stonefish is also well-equipped to defend itself. Its dorsal fin, unlike most other fish, has evolved to have 13 spines, which become erect whenever the stonefish feels threatened. Even a small amount of pressure on these spines causes venomous sacs to release extremely potent neurotoxins.



The stonefish is extremely well camouflaged; its prey won't notice its presence until it's too late

VS. KILLER WHALE

Number of teeth
40
7.6CM (3IN) LONG

Food consumed per day
227KG (500LB)

Length
UP TO
9.8M (32FT)

Maximum life expectancy
90 YEARS

Maximum swimming speed
50KM/H (31MPH)

SUCCESS RATE OF HUNTS CAN BE >75%

Adult weight
5,440KG (12,000LB)

SHARK SPEED

Most sharks swim along at a slow 2.4 kilometres (1.5 miles) per hour, but when it comes to catching their prey they can unleash ferocious speed.

Shortfin mako shark
These sharks are reportedly able to swim at 74 km/h (46 mph) in short bursts.

Great white shark
Once their target is locked, the great white can swim at speeds of 40 km/h (25 mph).

Blue shark
The blue shark has been measured at just under 40 km/h (25 mph).

Average shark
The average shark has a relatively slow cruise speed of 2.4km/h (1.5mph).

MORAY EELS

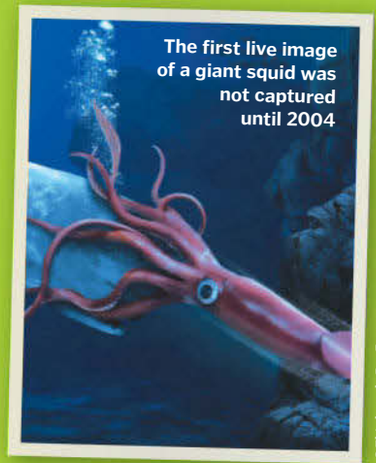
Moray eels are most commonly found lurking in the rocky crevices of temperate seas, often with just their heads visible. They aren't equipped with a pectoral fin which means that they aren't great swimmers, so they lie in wait to ambush their prey.

This slippery character possesses two sets of jaws, with a second set of raptorial jaws located in its pharynx. After taking the first bite, this second set of teeth moves forward and grabs hold of its victim, drawing the prey into its oesophagus to be swallowed. Although other fish species are known to have these second jaws, morays are the only animals known to be capable of using them to capture prey.

GIANT SQUIDS

The largest invertebrate on Earth is still a mystery to scientists. Giant squids are difficult to study due to their deep-sea habitat, meaning that almost everything we know about them has come from examining their carcasses – it wasn't until 2004 that a photo of a live specimen was taken.

How the giant squid hunts is still widely debated as it has never been witnessed. It's likely that the squid will ensnare prey in its tentacles before pulling the victim toward its sharp beak to be devoured. After the squid has chopped-up the prey into bite-sized chunks, it grinds them up further using the radula – an organ like a tongue covered in row-upon-row of teeth.



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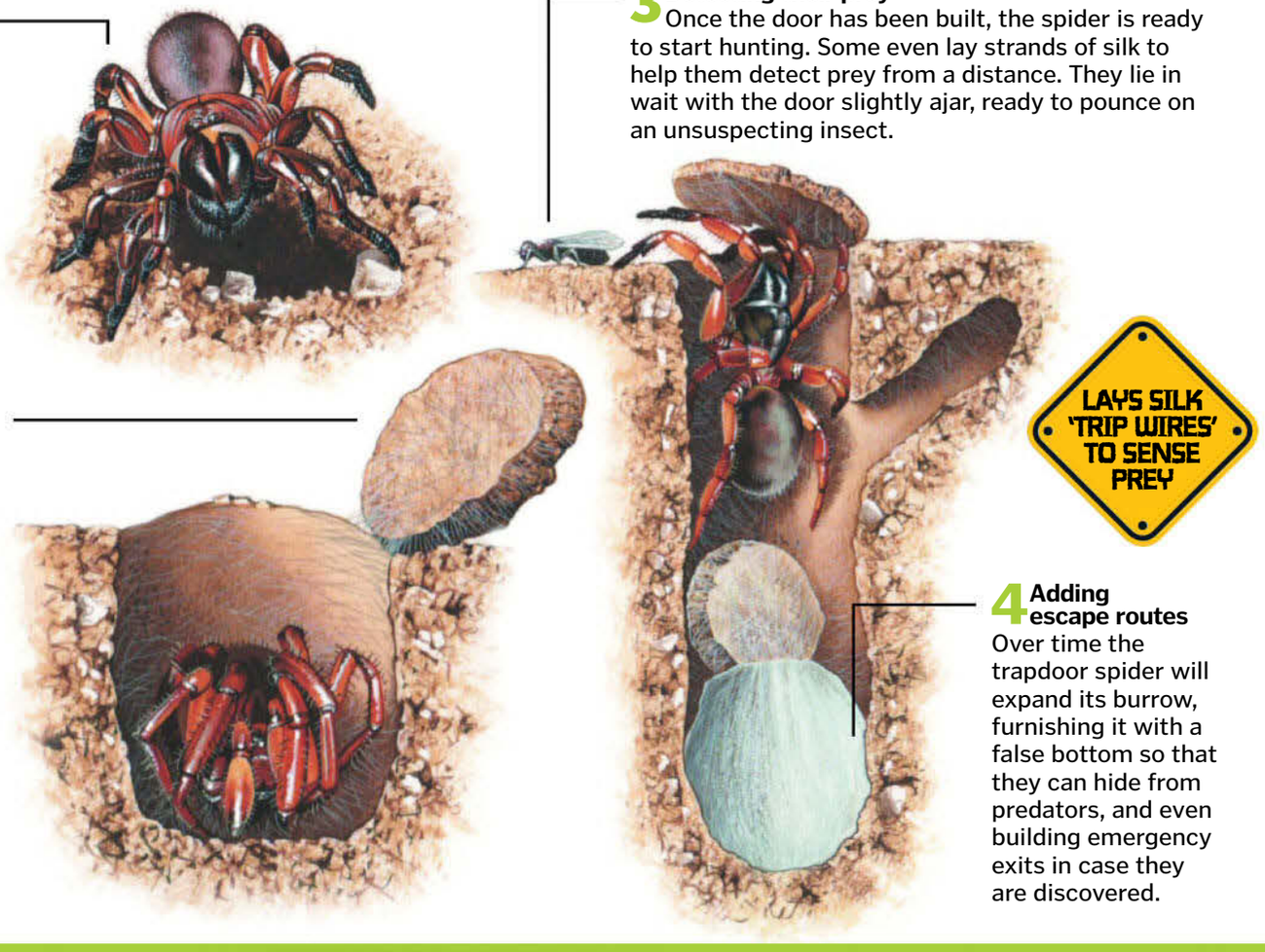
TRAPDOOR SPIDER

How this eight-legged attacker hunts its prey from a hidden lair

1 Building the burrow
The first part of their hunting process is to dig a burrow that only they can squeeze into. They employ their chelicerae (jaws) to clear away soil, and then remove it from the hole by wrapping it in silk.

2 Door construction
Using soil, clay or whatever is available to them, the spider builds a door that functions to block the burrow's entrance. It's reinforced by wrapping it in silk and then attached to the burrow with a silk hinge.

3 Detecting their prey
Once the door has been built, the spider is ready to start hunting. Some even lay strands of silk to help them detect prey from a distance. They lie in wait with the door slightly ajar, ready to pounce on an unsuspecting insect.



4 Adding escape routes
Over time the trapdoor spider will expand its burrow, furnishing it with a false bottom so that they can hide from predators, and even building emergency exits in case they are discovered.

BULLDOG ANT

Bulldog ants are commonly described as wasps without wings. The resemblance between them is no coincidence as ants are believed to have evolved from wasps millions of years ago.

Known for their aggression, bulldog ants both sting and bite when attacking their favourite prey, the carpenter ant. They have superb vision that is capable of identifying prey from up to one metre (three feet) away, and they tend to strike by jumping onto their victim's back and repeatedly stinging it with deadly doses of venom.

A bulldog ant's mandible typically has 12 to 13 teeth, ready to clamp down on its victim

The praying mantis will often hide and look for prey with its two large compound eyes

PRAYING MANTIS

These insects may be no bigger than your average teacup, but they have mastered a lethal hunting technique. Once their prey is in reach, this predator lunges forward in 0.05 seconds, impaling its victim with razor-sharp raptorial forelegs. These reflexes are so fast that many people would struggle to see it move with the naked eye. Once its legs have pierced the prey, the praying mantis holds on and bites into its head using its teeth. They feast on lizards, frogs, mice and even birds that are three times their size.

ORB-WEAVER SPIDER

The orb-weaver spider is an unusual spider as it builds a new web everyday, removing its existing web at dawn and hiding from potential predators during the day. Once the Sun begins to set, the orb weaver sets about building a new web, spinning steely strands of silk to create a web of concentric circles. Once its victim lands on the web it picks up on the vibrations, before quickly pouncing and trapping its prey in a silken cocoon. One quick bite paralyses its meal, enabling the spider to chow down with no fuss.

The orb-weaver eats a range of insects, from ants and grasshoppers to moths and dragonflies (pictured)

KOMODO DRAGON

How the largest lizard on Earth takes down water buffalo

This real-life dragon is far more fascinating than any mythical beast of fiction. These powerful lizards are opportunistic carnivores and eat almost anything they can find, including the young of their own species! There aren't many kinds of meat that a Komodo dragon will turn its snout up at – with their keen sense of smell they can detect and track down carrion from several kilometres away.

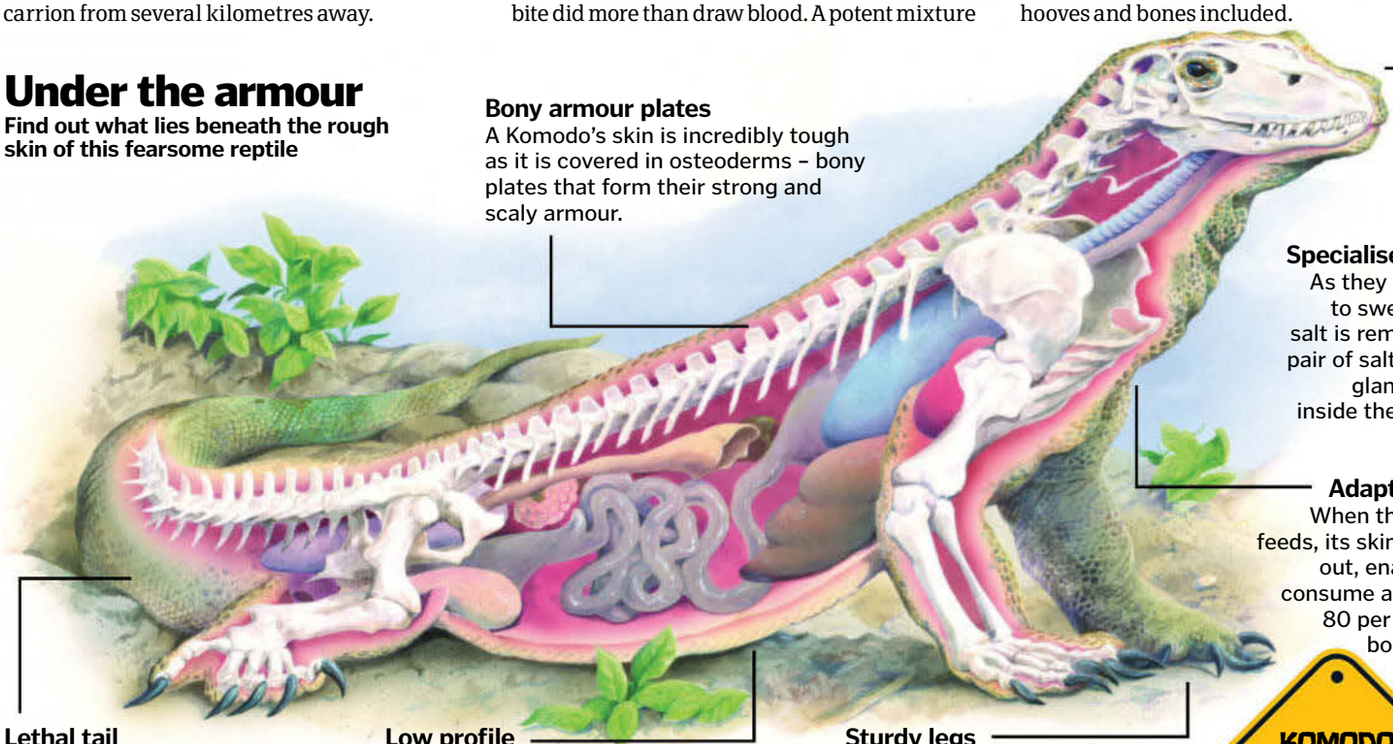
The Komodo dragon's sharp teeth are curved and serrated – perfect for tearing chunks of flesh from its prey. Its killer move is the belly bite, which the Komodo will use to bring down larger victims like water buffalo. The bite itself is rarely fatal, allowing the target to evade capture, but victory is short-lived.

The dragon knows the damage is done as its bite did more than draw blood. A potent mixture of chemicals from its venom glands seeps into the wound, preventing the blood from clotting, so their victims eventually bleed to death.

With a flicker of its forked tongue, the Komodo tracks the buffalo's location by scent and will devour almost every part of its prey – hide, hooves and bones included.

Under the armour

Find out what lies beneath the rough skin of this fearsome reptile



Bony armour plates
A Komodo's skin is incredibly tough as it is covered in osteoderms – bony plates that form their strong and scaly armour.

Specialised glands
As they are unable to sweat, excess salt is removed via a pair of salt-secreting glands housed inside their nostrils.

Adaptable skin
When the Komodo feeds, its skin stretches out, enabling it to consume a whopping 80 per cent of its body weight!

Lethal tail
Measuring the same length as its main body, the tail is composed of thick muscle. The Komodo is capable of knocking over an adult deer with one swipe.

Low profile
The Komodo is huge, typically measuring over two metres (6.6ft) in length, but they stand at a height of only 40cm (15.7in), which enables them to sneak up on their prey.

Sturdy legs
The legs of a Komodo bow outwards, forcing them to weave as they walk. Each foot has five lethally sharp claws.

KOMODO DRAGONS ARE KNOWN TO ATTACK HUMANS UNPROVOKED

HOW A DRAGON KILLS

THEORY 1
DEADLY PATHOGENS

For many years it was believed that Komodos killed by infecting their prey with bacteria found in their mouths, but it turns out that this isn't the case. Levels of oral bacteria were too low to infect something as large as a water buffalo, which completely rules out this theory.

THEORY 2
VENOM

Back in 2009, scans of a Komodo's head found two previously undiscovered venom glands in the dragon's lower jaw. These scans also demonstrated the self-inflicted damage that their 'grip and rip' attacks can cause on their jawbones.

THEORY 3
DEVASTATING ATTACK

The combination of venom delivery and vicious attack is now the prevailing theory as to how Komodos kill. They are able to deliver toxic proteins via gaps between their teeth, so that when they bite with their serrated teeth, venom oozes into the wound.

© Thinkstock

THE BALD EAGLE

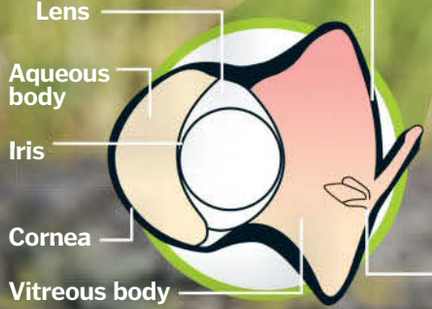
Designed to hunt, this eagle possesses a number of anatomical features that enable it to overpower even large animals

DIVES AT SPEEDS OF UP TO 100MPH (160KPH)

Detailed vision
The eagle's eyes are huge, taking up the majority of its skull. They provide the bird with excellent eyesight that is four times better than a human's.

Sharp beak
The bald eagle's beak is coated in keratin which grows continually to ensure the beak's edge is always razor-sharp.

Fovea
Unusually, an eagle's eye has two focal points enabling it to look forwards and to the side – perfect for spotting prey.

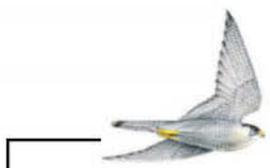


Pecten oculi
This additional blood supply to the back of the eye reduces the number of blood vessels covering the retina, providing clearer vision than mammals. Reptiles also have this in their eyes.

Vast wingspan
Measuring sometimes over two metres (seven feet), the eagle's wings are designed to catch warm air currents. Its feathers continually grow much like our own hair and nails.

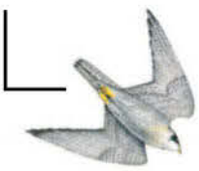
Broad sternum
The eagle has a large breastbone to which its flight muscles are attached. The eagle's muscular chest powers the downbeat of its huge wings.

Deadly talons
Talons are the eagle's primary weapon. Their vice-like grip is believed to be ten times stronger than that of a human.



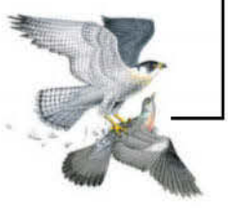
Spotting a victim
The peregrine flies up to one kilometre (0.6 miles) above the ground to locate a potential victim, using warm columns of air, known as thermals, to fly up.

Roll
Once the peregrine has located its prey of choice, it rolls into position so that it's ready to start its assault.



Attack
The peregrine dives and crashes into its victim at around 322km/h (200mph). This impact alone can kill, but its main goal is to incapacitate the victim so that it can be carried away in the falcon's talons and eaten elsewhere.

Wing tuck
By tucking in its wings the peregrine takes on an aerodynamic teardrop shape, bracing it to perform its stoop dive attack.



PEREGRINE FALCON

The peregrine falcon is adapted for one main purpose – speed. Thought to be the fastest animal to ever have inhabited the Earth, it is a formidable predator equipped with a hooked beak for tearing flesh and sharp talons to keep prey locked in their grasp. When diving it can reach speeds that triple that of a sprinting cheetah, and can freefall faster than a human skydiver.

Its wings exhibit specialised flight feathers; the muscles make up roughly a fifth of its entire body weight, and it even has a protective third eyelid that's transparent so they can keep an eye on their prey. This immense hunting ability enables the peregrine to feed on medium-sized birds, such as pigeons and doves.

TOP 5 PEOPLE KILLERS

(numbers are human deaths per year)

Mosquitoes
725,000

Snakes
50,000

Dogs
25,000

Tsetse fly
10,000

Assassin bug
10,000

The statistics don't lie; mosquitoes are the biggest killer of humans. They may not be classed as a predator, but their ability to kill through transmitting malaria means that they present the biggest threat to humans. Between 300 and 500 million cases of malaria occur each year, and it's estimated that a child dies from the disease every 30 seconds. Snakes rank second mainly due to the lack of antivenin in many parts of the world, and dogs come in third due to their ability to spread rabies. Iconic predators such as the shark kill only ten people a year, yet elephants kill around 100.

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WIN A SHARK ENCOUNTER!

Come face-to-face with one of the ocean's deadliest predators

We've teamed up with the Blue Planet Aquarium in Chester, UK, to give you a chance to win a once-in-a-lifetime shark encounter worth over £200. This diving experience will enable you to get up close and personal with the aquarium's collection of three-metre (ten-foot) sand tiger sharks, with no cage in site. Before you enter the Caribbean reef exhibit's 3.8 million-litre (1 million-gallon) tank, you will receive full dive training and use of SCUBA equipment. Qualified divers will accompany you throughout the encounter, and afterwards you will receive an "I Dived with the Sharks at Blue Planet Aquarium" certificate to take home and treasure. You will also get free entry for two spectators, who will be able to take photos of your dive as further proof of your remarkable bravery.

The lucky winner of this amazing prize will receive a voucher for one shark encounter, redeemable within six months of winning the competition. Before getting into the tank they will also need to pass a medical questionnaire and self-certify their general health and well-being.

How to enter:

For a chance to win a shark encounter worth £210, visit **howitworksdaily.com** and answer the following question by 9 September 2015.

Which of these is not a species of shark?

A) Tiger shark

B) Great white shark

C) Kitten shark

BLUE PLANET AQUARIUM

blueplanetaquarium.com

This competition is open to residents of the United Kingdom and Ireland. Imagine Publishing has the right to substitute the prize with a similar item of equal or higher value. Employees of Imagine Publishing (including freelancers), Blue Plane Aquarium, their relatives or any agents are not eligible to enter. The Editor's decision is final and no correspondence will be entered into. Prizes cannot be exchanged for cash. Full terms and conditions are available on request.

© Blue Planet Aquarium

The flammable Lake Abraham

What forms the explosive bubbles trapped beneath these frozen waters?

It may look spectacular, but this frozen lake should be approached with caution, particularly if you're holding a lit match. The incredible white patterns visible within the ice are actually bubbles of methane, a highly flammable gas. As the lake melts in spring, these bubbles are able to reach the surface where they pop, allowing the methane to escape. Some brave scientists have even tested the presence of this gas by poking holes in the ice and holding a lighter over the surface, sending huge flames into the air.

The methane is produced by bacteria that feeds on organic matter, like leaves and dead animals, for example, which have fallen into the lake. In addition, because the man-made lake bed was covered in trees, grass and plants before it was flooded in 1972, it contains much more organic matter than any natural lake would. This has given the bacteria more to feast on, which causes them to produce a larger amount of methane.

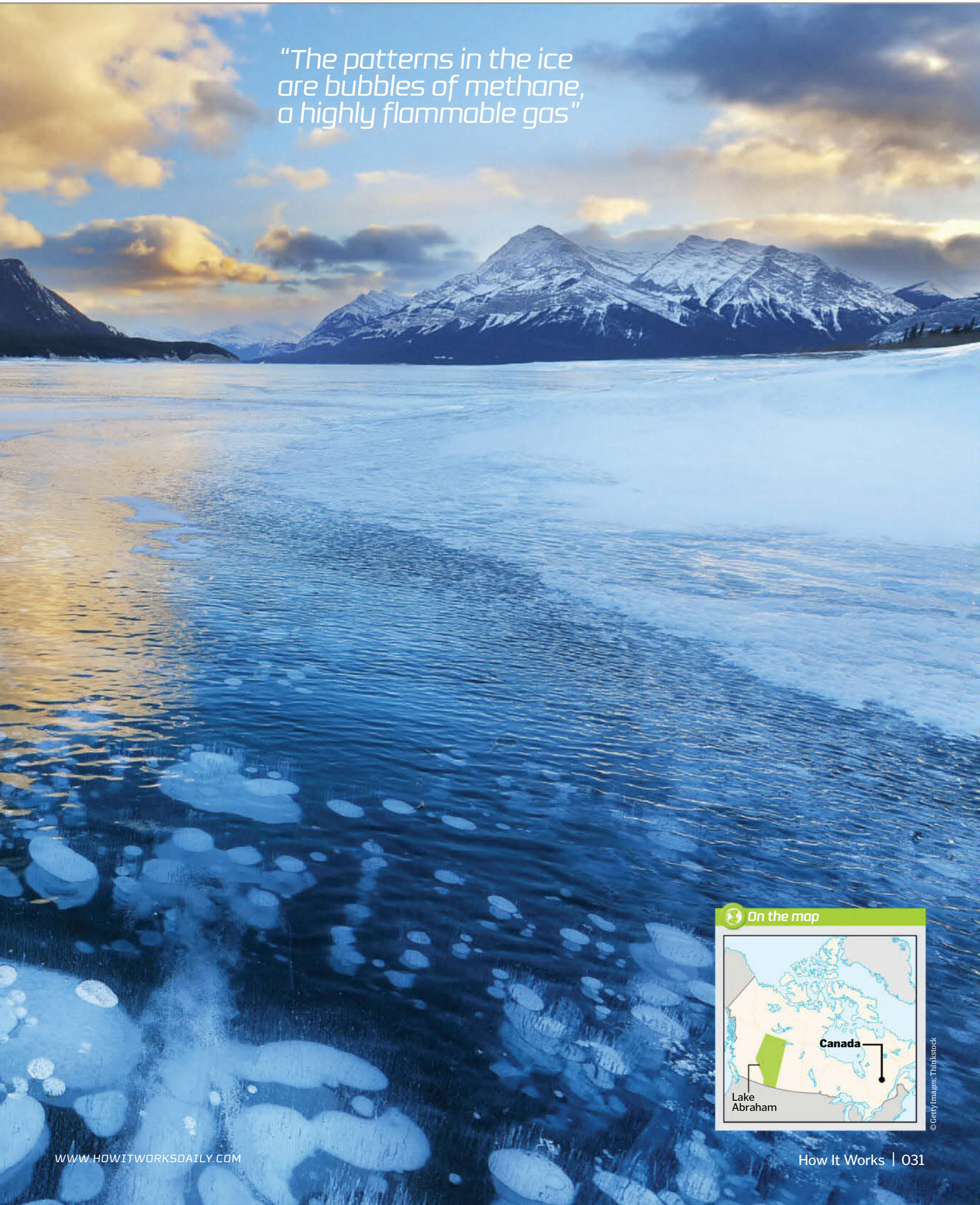
However, although the lake is great for putting on amazing fire shows, it is not so good for climate change. Methane is a greenhouse gas 25 times more potent than carbon dioxide, trapping heat in the Earth's atmosphere to cause global warming. This is also creating a vicious cycle. As warmer temperatures cause more of the frozen ground around the lake to thaw and collapse, more trees fall into the water. This increase in organic matter in the lake leads to more methane production. The amount of methane released by Lake Abraham alone won't have much effect, but there are thousands of other bodies of water around the Arctic producing it too. Scientists estimate that more than ten times the amount of methane currently in the Earth's atmosphere will come out of these lakes in the near future.

AMAZING VIDEO!

Watch some scientists set fire to a methane lake!

www.howitworksdaily.com

DID YOU KNOW? *Methane lakes can be used an energy source. Some countries harvest the gas and use it to make electricity*



"The patterns in the ice are bubbles of methane, a highly flammable gas"

On the map

©GettyImages/Thinkstock

Stromatolites

Could these odd rock structures be the earliest signs of life?

In spite of their understated appearance, stromatolites have been majorly important in Earth's evolutionary history

They might not look like much, but stromatolites are the oldest fossils to be found on Earth. They are essentially layered mounds of sediment and calcium carbonate that build up around colonies of single-celled organisms like cyanobacteria, a photosynthesising microbe which can still be found today.

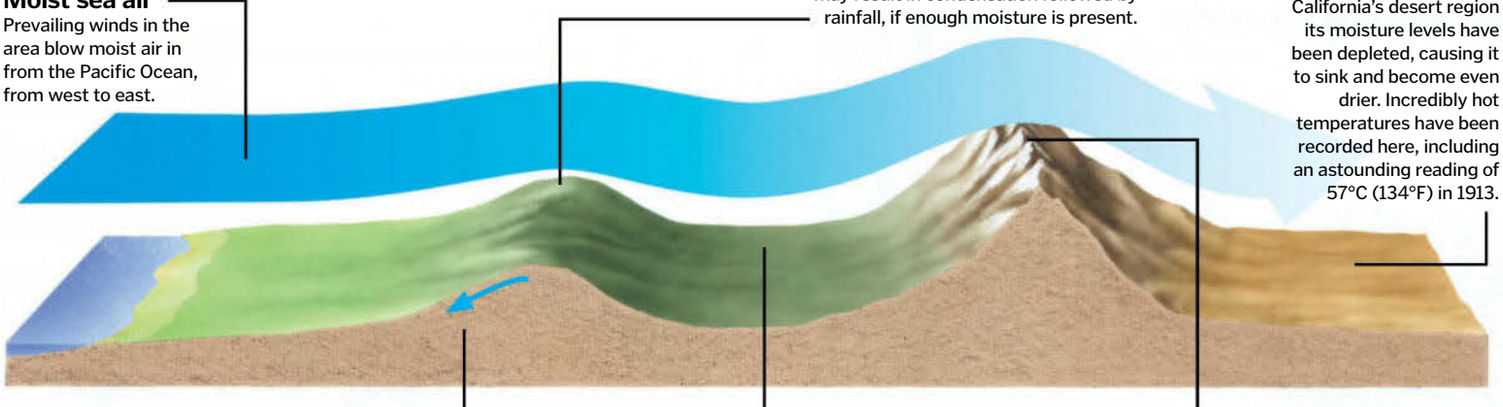
When fully formed they resemble boulders, but they are actually composed of layer upon layer of material accumulated by the cyanobacteria, trapped by the mucus they produce naturally. As these bacteria photosynthesised they used up carbon dioxide in the surrounding water, causing calcium carbonate to precipitate out and also become trapped in the layers along with grains of sediment.

These layers would slowly build up on top of one another, with the bacteria migrating upwards through the sediment to remain on the top level. A well-developed stromatolite mound is likely to represent at least 10,000 years of growth and will often contain a myriad of shapes depending on the environment in which it grew.

It's believed that the continued formation of stromatolites aided the creation of a breathable atmosphere, due to the vast quantities of oxygen produced by the photosynthetic bacteria. This underlies their significance; human life may not have been possible if these tiny organisms had not come into existence.

California's climate zones

From moist sea air to dry desert, find out why North California has such a unique climate



Moist sea air
Prevailing winds in the area blow moist air in from the Pacific Ocean, from west to east.

Coastal mountains
As sea air rises over the coastal mountains it expands and cools, which may result in condensation followed by rainfall, if enough moisture is present.

Great Basin
By the time air reaches the California's desert region its moisture levels have been depleted, causing it to sink and become even drier. Incredibly hot temperatures have been recorded here, including an astounding reading of 57°C (134°F) in 1913.

Groundwater flow
Both stream run-off and groundwater flow carry dissolved salts back to the ocean, contributing to the ocean's salt concentration. Evaporation is also a factor in ocean salinity.

Central Valley
The sea air sinks down once it passes the coastal mountains, becoming drier. Following this, it regains some of its moisture through evaporation and plant transpiration. These two processes occasionally result in the formation of fog.

Sierra Nevada
As air is forced to rise over the high mountains of the Sierra Nevada region, it undergoes further cooling which usually results in more rainfall, or snow in the winter. This mountain range is approximately 110km (70mi) wide and has a significant impact on California's climate.

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BUILT FOR ADVENTURE

HAWK T100

SUPERLIGHT
POLYCARBONATE CASE

T100 GTLS
SELF - POWERED
ILLUMINATION

IN THE PHOTO:
Camping underneath the Aurora Borealis,
Iceland. Captured by Tim Nunn.

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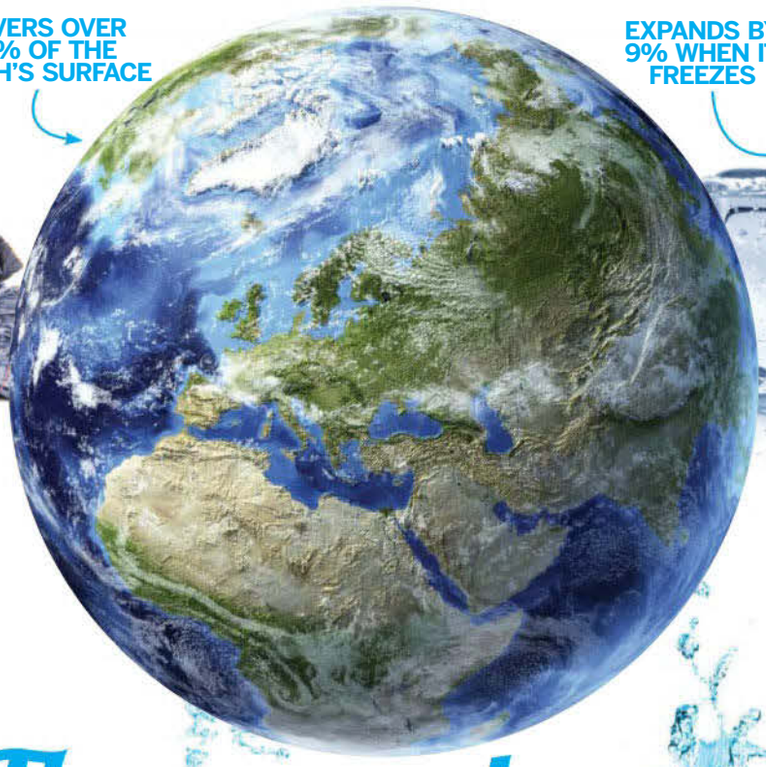
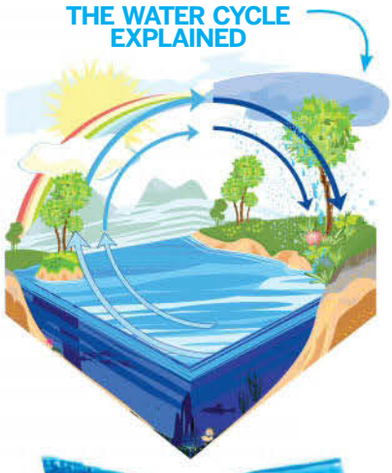
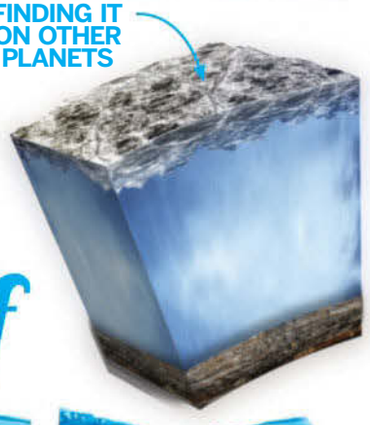






The wonders of WATER

Discover why this colourless chemical compound is the key to life

A water molecule is composed of just three atoms – one oxygen and two hydrogens. It is smaller than a molecule of carbon dioxide and, based on size, alone should float around as a gas at room temperature, but instead water molecules manage to hold together as a liquid. This remarkable feat is down to a phenomenon known as hydrogen bonding.

The chemistry of water means that one side of the molecule is positively charged and the other side is negatively charged. When one molecule comes close to another, these charges attract forming a temporary attachment called a hydrogen bond. These sticky interactions are responsible for many of the amazing properties of water, including its ability to exist in all three states – solid, liquid and gas – under the range of temperatures and pressures that can be experienced on Earth.

The temporary attachments between water molecules enable it to remain liquid over a range of at least 100 degrees Celsius (180 degrees Fahrenheit), or even more if the water is salty or under pressure. This means that Earth's rivers and oceans remain stable even as the climate fluctuates. It is because water can freeze, thaw, evaporate and condense within the normal range of temperatures on Earth that we have our weather system. Water molecules can make up to four hydrogen bonds with their neighbours, but in liquid form this almost never happens.

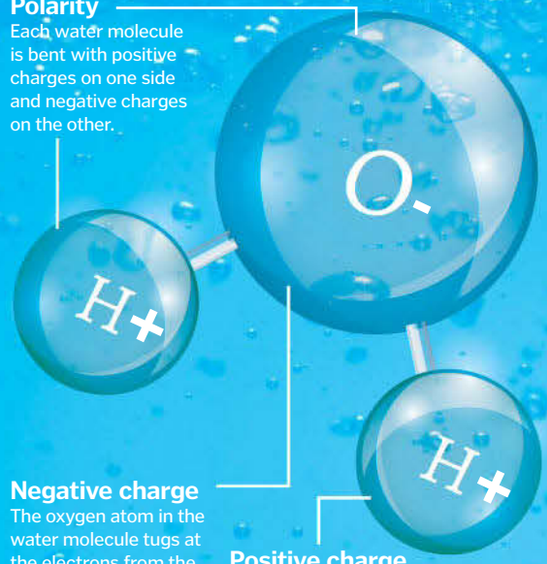
However, as water cools below zero degrees Celsius (32 degrees Fahrenheit), the molecules line up to form rigid crystals to maximise these bonds. This structure has lots of gaps, making it less dense than liquid water, causing the ice to float. This strange property is critical to the role of water in maintaining Earth's climate, and in supporting life as we know it. If ice did not float, lakes would freeze from the bottom up, turning completely solid over the course of the winter.

Water is also one of the best solvents in the known universe. The polar molecules can dissolve other charged particles, and even uncharged particles can be pulled into solution under the right conditions. This has many effects, from altering the geology of the planet to bringing biological molecules close enough for the chemistry of life to occur. Water is essential to life as we know it and as we have progressed on our watery world, we've harnessed its power to achieve incredible things.

What is water?

Water is made up of two key ingredients: hydrogen and oxygen. Each molecule contains one oxygen atom at the centre, bonded to two hydrogen atoms positioned 107.5 degrees apart.

These key pieces of chemistry give water its unique properties. Oxygen is electronegative – it has a tendency to attract negatively charged electrons. This means that it tugs at the electrons belonging to the two hydrogen atoms in the molecule, and because the water molecule is bent it ends up positively charged on one side and negatively charged on the other.



Polarity
Each water molecule is bent with positive charges on one side and negative charges on the other.

Negative charge
The oxygen atom in the water molecule tugs at the electrons from the hydrogen atoms, gaining a slightly negative charge.

Positive charge
The hydrogen atoms lend their electrons to the oxygen atom, becoming slightly positively charged.

Solid
When water freezes, the molecules line up to form an orderly crystal structure. The bends in the molecules prevent them packing too closely, leaving lots of tiny gaps.

Liquid
Strangely, in liquid form, water molecules are able to get closer. The positive and negative charges pull the molecules together, making water denser than ice.

Gas
If water molecules are given enough energy they can break away from the pull of their neighbours, moving apart and forming a gas known as water vapour.

Water in the body

More than half of your body is water and everything that happens inside you depends on it. Water is the solvent that enables vital biochemical processes to occur. It dissolves the chemical building blocks of life, preparing them for transport and construction.

Without water, the body rapidly starts to malfunction. The effects are noticeable when just two per cent of total body water is lost, but if the amount drops to over 15 per cent, it can be fatal. With less water in the blood, the heart must work harder. Rising levels of salt cause muscles to spasm and water loss from the brain leads headaches, dizziness and confusion. Eventually, multiple organs start to fail.

Brain
Water in the central nervous system acts as a shock absorber, protecting the brain and spinal cord from damage.

Defence
Water is used to produce tears, saliva and mucus, helping to protect our bodies from infections and irritants.

Blood
Water in the blood acts as a carrier, transporting red and white blood cells, gasses and nutrients around the body.

70%
OR MORE OF OUR BRAIN IS WATER

Kidneys
The kidneys use water to wash away waste products, like excess salt and urea.

Digestive system
Water helps to keep food moving through the digestive system, allowing enzymes to access the nutrients inside.

50%
OF OUR BLOOD IS WATER

Skin
Water helps to regulate body temperature by carrying excess heat away from the skin as it evaporates.

2 LITRES PER HOUR
HOW MUCH WATER WE CAN LOSE DURING INTENSE EXERCISE

Bones
Bones might look dry, but they are around 25% water by weight, helping nutrients to reach the living cells inside.

400-2,000ml
HOW MUCH URINE WE PRODUCE EACH DAY

© Thinkstock; Dreamstime

HOW WE USE WATER

Our lives have been tied to water since the very beginning

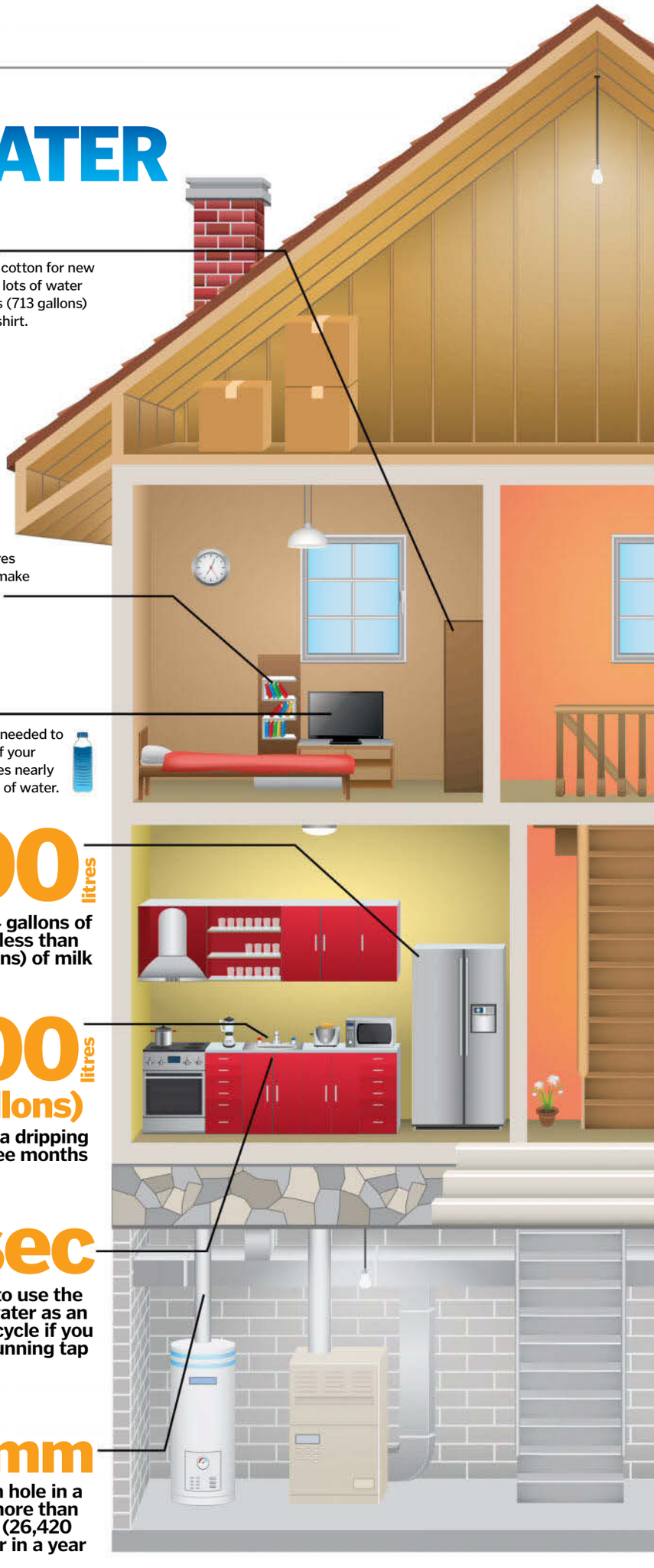
It is no coincidence that cities like London, Paris and New York straddle vast rivers. We depend on water for our survival. For millions of years, our ancestors chased after this precious resource, but a few thousand years ago modern humans started to tame it.

The major technological advancement that changed our relationship with water was agriculture. From around 10,000 BCE humans gradually stopped hunting and gathering, and began cultivating crops and keeping livestock. Pioneering farmers in Ancient Egypt and Mesopotamia dug drains and channels to regulate water flow to their fields, and in Ancient China, the Yangtze river basin was adapted to create paddy fields for growing rice.

This infrastructure paved the way for the expansion of local settlements, and as water communities worked together to handle periods of flood and drought, they transformed arid landscapes into productive oases. The ability to develop the land and to grow food to meet or even exceed demand, has been one of the keystones in the development of the modern world. To this day, agriculture is still the single largest use of freshwater on the planet, accounting for almost three quarters of the water we use each day.

Water is also used for transport and exploration, and carried our ancestors and their belongings to all corners of the Earth. This facilitated a global trade of objects and ideas, paving the way for the development of new technologies, like the water wheel. First used to move water from one place to another, water wheels were later harnessed to perform work. The Ancient Greeks were some of the first to capture their power to grind grain more than 2,000 years ago. By 1880, this technology had been adapted to produce electricity to power lights and today we have transformed the old-fashioned water wheel into modern hydroelectric turbines.

The invention of the water wheel led to the development of pumps and valves, and when the first reliable steam engine was built in 1775, it drove the Industrial Revolution and changed the world forever. Today, around 20 per cent of the water used every day on this planet is consumed by industry, playing a vital role in the generation of power and in the manufacture of goods. Only a small amount of water is used in the home – much of this for cleaning and sanitation – and amazingly, just fractions of a per cent of our daily freshwater is actually used for drinking.



Clothes
Growing the cotton for new clothes uses lots of water – 2,700 litres (713 gallons) for just one shirt.

x1,350

We only drink
1%
of the water we use every day

Books
It takes more than ten litres (2.6 gallons) of water to make a single sheet of paper.

Electricity
Making the electricity needed to watch nine episodes of your favourite television uses nearly two litres (0.5 gallons) of water.

1,000 litres
It takes around 264 gallons of water to produce less than one litre (0.26 gallons) of milk

5,000 litres (1,321 gallons)
How much water a dripping tap wastes in three months

60sec
The time it takes to use the same amount of water as an entire dishwasher cycle if you wash up under a running tap

1.5mm
A tiny 0.06-inch hole in a pipe can leak more than 100,000 litres (26,420 gallons) of water in a year

= 2 litres

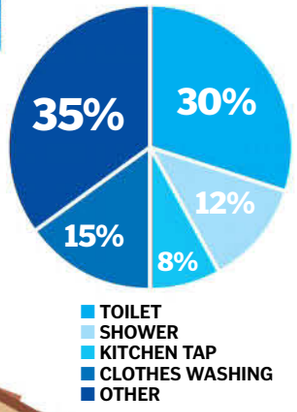
2x **A bath uses almost twice as much water as a five-minute shower – 80 litres (21 gallons) versus just 45 litres (12 gallons)**

Tooth brushing

Leaving the tap on while cleaning your teeth wastes around 12 litres (3.2 gallons) of water, enough to fill a large bucket.

Toilet flushes

Over a quarter of the water you use each day goes down the toilet. Each household flushes around 5,000 times a year.



Radiator

The average radiator contains around five litres (1.3 gallons) of water.

180,000 litres

It takes over 47,551 gallons of water to make a new car

Washing the car

Using a garden hose for an hour can use 500 litres (132 gallons) of water – enough to fill a bathtub six times. x250

Cleaning clothes

Depending on how old your washing machine is, it can use between 50 and 150 litres (13 and 40 gallons) per cycle. x25-75

150 litres

The average amount of water each person in the UK uses per day

Agriculture

Agriculture accounts for around 70 per cent of the total global use of fresh water. In the United States alone, over 484 billion litres (128 billion gallons) of water is used for crop irrigation every single day. Water from rivers, lakes, wells and reservoirs is diverted for use on the land, watering crops, feeding livestock, and cleaning produce ready for sale.

Industry

After agriculture, industry is the second largest consumer of freshwater, accounting for around 20 per cent of global usage. It is used in manufacture, processing, washing, cooling and transport, and is included as a component of many products from soaps to soft drinks. In the USA, over 65 billion litres (17.3 billion gallons) of water are used by industry every day.

Municipal

Public use of water accounts for only around eight per cent of the fresh water usage worldwide. In cities, much of this water is used in gardens and for washing and sanitation. Despite the fact that all of the water that comes into our homes is safe to drink, only a very small percentage is actually used for this purpose.

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THE WATER CYCLE

The water that we see on Earth today is the same water that was here at the time of the dinosaurs. It is constantly recycled in a circular system powered by the Sun. During the day, water on the surface of the Earth is heated. As the molecules gain energy, they start to break free from the hydrogen bonds that hold them close to their neighbours and they become water vapour.

The vapour is carried up into the atmosphere by rising currents and as it climbs higher, it starts to cool. The vapour starts to condense to form water droplets, which then gather together in vast clouds. Air currents high in the atmosphere transport the clouds across the globe, blowing the droplets far from their origin, but as more vapour condenses they gradually become much too heavy to remain suspended in the sky. Depending on the temperature, the water eventually falls back to the ground as rain, hail or snow.

This water can fall directly into a river or ocean, or it can take a more convoluted path back to the beginning of the water cycle. Much of the water that hits the ground runs straight off and into the nearest body of water. Some seeps into the soil and is sucked up by thirsty plants, and some flows into underground reservoirs. Some water freezes at the top of slow-moving glaciers, but eventually, it all makes its way back to the start.

1 Evaporation and transpiration

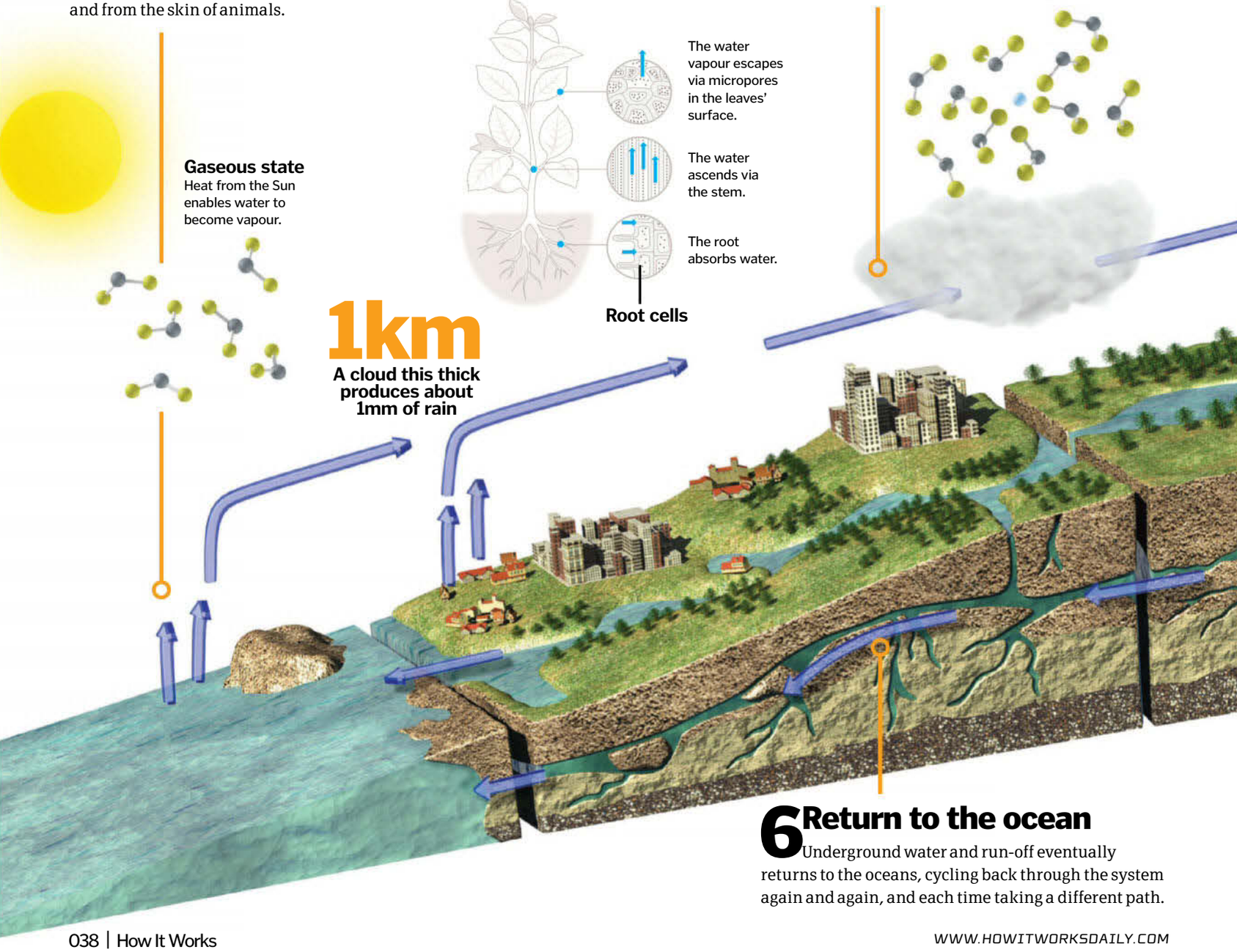
The Sun warms water in the oceans and on the Earth's surface, causing it to evaporate. Water is also lost from the leaves of plants and from the skin of animals.

80%

of evaporation is from the oceans

2 Condensation

As water vapour climbs high in the atmosphere, the temperature drops and it condenses around particles of dust in the air, forming clouds of tiny water droplets.



6 Return to the ocean

Underground water and run-off eventually returns to the oceans, cycling back through the system again and again, and each time taking a different path.

Water availability Cubic feet per capita/year

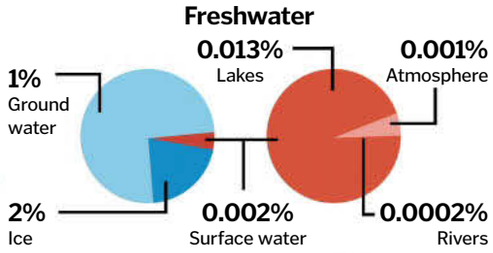
- Less than 1,700m³ (60,000ft³)
- 1,700-5,000m³ (60,000-175,000ft³)
- More than 5,000m³ (175,000ft³)

Almost 80% of the world's population has access to drinking water

Where it is found

3% Freshwater **97%** Salt water

A small percentage is freshwater; most of it is salt water.



Solid state

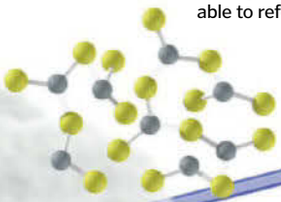
Water molecules form orderly crystals in ice and snow.

3 Precipitation

As more water condenses in the clouds, the droplets become too heavy to remain suspended in the air and they fall to the ground as rain, hail, sleet or snow.

Liquid state

As the vapour cools, hydrogen bonds are able to reform.



57,0000

litres of water flow over Niagara Falls each second

5 Underground circulation

Some water travels underground, gathering in reservoirs, flowing in buried streams, dripping through pores and channels in the rocks, or creeping along as glacial ice.

500

quadrillion litres of rain falls every year

4 Run-off

Much of the water that falls to the Earth as rain runs straight off the ground and back into lakes, streams, rivers and oceans. This is more common in environments that have frequent rain.

© Solpo

WATER IN SPACE

Why has the search for life become the search for water?

Life and water are inextricably linked. Life as we know it needs a solvent in order to exist – a liquid carrier that can dissolve biological molecules, allowing them to come into contact and therefore enabling the chemistry of life to occur. Water is the only molecule known to be able to perform this function.

Water is quite unlike any other solvent in the known universe. Its chemical structure means that one side of each molecule is positively charged and the other side of each molecule is negatively charged. This makes water molecules sticky, attracting anything else with a positive or negative charge, including other water molecules and other charged particles, like salts, for example.

There are other liquids that have been suggested as possible biological solvents, including methane, but none is quite like water. Because water is polar and its molecules are sticky, it can hold together as liquid at temperatures that would turn other similarly sized molecules to gas. Water remains liquid over a relatively large range of temperatures, a property that has been vital for the development of life on Earth.

In order for methane to be found in its liquid form, the temperature needs to be lower than -161 degrees Celsius (-258 degrees Fahrenheit). Liquid methane seas do exist on Saturn's moon Titan, but molecules at this temperature move around so little that biological reactions would have to occur in extreme slow motion.

The arrival of water on Earth was the catalyst that enabled life to evolve. Early Earth was hot and inhospitable, but around 400-600 million years after its formation, things started to change. This period was known as the Late Heavy Bombardment. Earth was pummelled by rock and ice flung in from the far reaches of the Solar System by the immense gravitational interactions of Jupiter, Saturn, Neptune and Uranus. The rocks brought ice with them which melted to form liquid water.

All life discovered on Earth so far depends on this water for survival, so in the search for life elsewhere in the Solar System, scientists are focussing on finding water in its liquid form. If the conditions are right, liquid water on other planets or moons in the Solar System could have supported extraterrestrial life in the past, or possibly to this day.

Water on Mars

There is mounting evidence to suggest that Mars was once much warmer and wetter than it is today. NASA's Curiosity rover recently found evidence of liquid water in the soil below the surface of the Red Planet, but the environment is thought much too hostile for there to be any life existing on Mars today.

Other moons
Many of the moons in our own Solar System contain liquid water, and so might other moons in the Milky Way and beyond.

87%
Amount of Mars' original water lost to space

The Moon
Several spacecraft have detected evidence of water ice at the lunar poles.

Saturn's moons
Saturn has at least 53 natural satellites. One of these, Enceladus, is home to massive ice volcanoes.

Other galaxies
Water is quite common in the universe, and watery planets like our own are likely to exist in other galaxies.

Quasars
The largest reservoir of water in the known universe was found surrounding a black hole in a feeding frenzy.

Comets
These balls of frozen gas and dust contain water from the farthest reaches of the Solar System.

Habitable zone
Astronomers expect life to be most likely on planets that are the right distance from the Sun for liquid water to exist.

Asteroids
The asteroids that we see today contain little water, but earlier in the history of the Solar System they would have carried ice.

Space oceans

The largest oceans in the Solar System are found on moons

Europa
Moon of Jupiter
The intense gravitational pull of Jupiter causes friction on the icy moon Europa, generating enough heat to maintain liquid water below its surface. It is home to a vast ocean with more water than all of Earth's oceans combined.

Enceladus
Moon of Saturn
About seven times smaller than our own Moon, Enceladus is heated by the tidal effects of Saturn. Its geysers spit water vapour into space at speeds of about 400 metres (1,312 feet) per second.

Ganymede
Moon of Jupiter
Ganymede is larger than Mercury and is thought to be home to a sub-surface ocean that contains more water than there is on Earth's surface.

100km
The thickness of Europa's sub-surface water layer

Water on Comets

We used to think that Earth's water came from comets, but in 2014 the European Space Agency's Rosetta probe discovered that the water on comets is different to the water on Earth. It is therefore more likely that water was delivered to the early Earth by rocky asteroids.

Water in space

The largest and most distant volume of water ever found in the universe is caught in the clutches of an enormous black hole, over 12 billion light years away. The cosmic reservoir hosts approximately 140 trillion times the amount of water there is in Earth's oceans.

Nebulae
The ingredients of water, hydrogen and oxygen, are responsible for the colourful glow of some nebulae.

Star birth
Water can be found in the clouds of dust and gas that surround the birth of new stars.

© DLR German Aerospace Centre; NASA/ESA

How has Antarctica's ozone hole changed?

Find out what triggered the colossal ozone hole to form

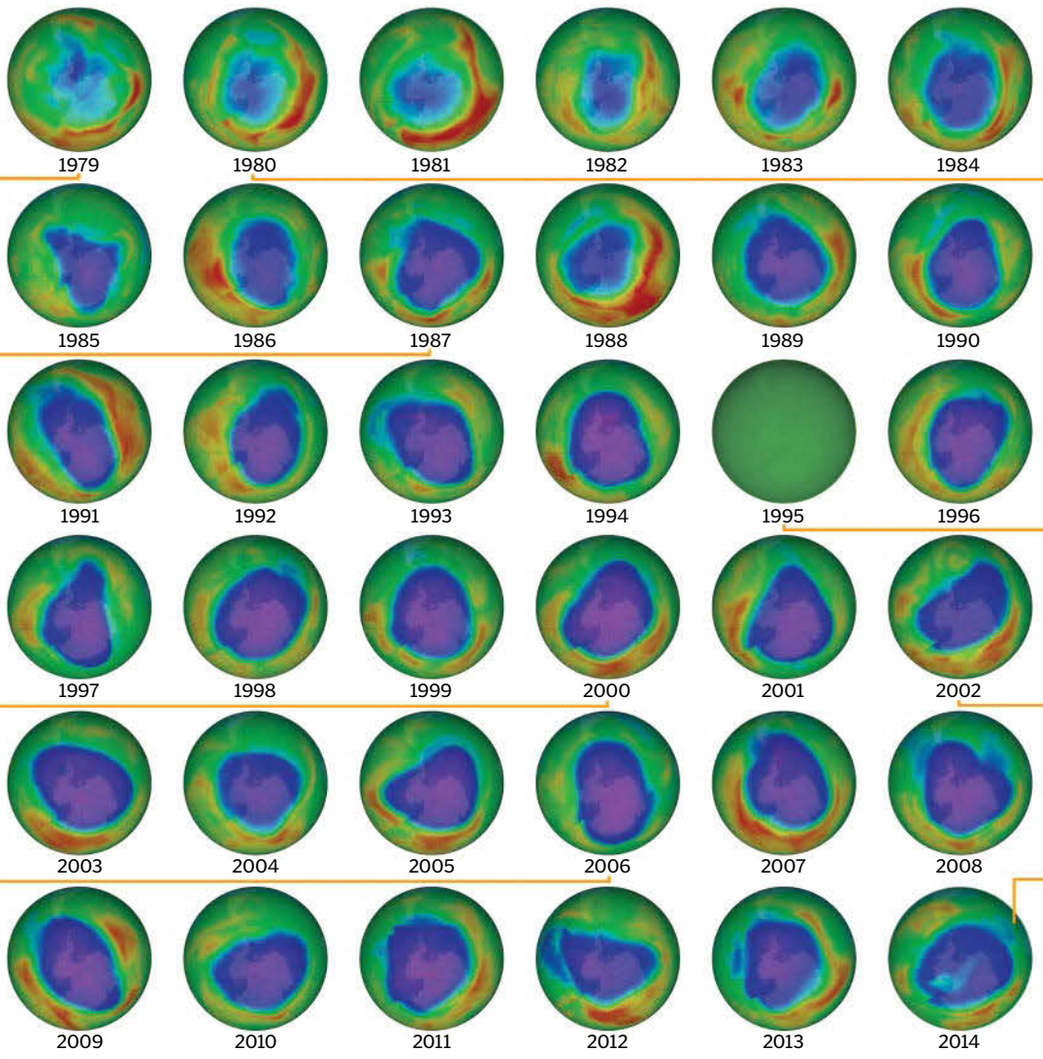
The destruction of the ozone layer is widely recognised as one of Earth's most troubling environmental issues. Of particular concern is the hole that has formed in Antarctica's ozone layer, which was first observed during the 1970s and continued to grow until 2006. This is not an actual 'hole', it is simply an area of seriously depleted ozone which has a value of 220 Dobson Units (a measure for ozone density) or less. The cut off point is set at this value because readings lower than 220 Dobson Units had not been recorded prior to 1979.

Ozone damage is caused by chlorofluorocarbons, or CFCs, which were once used in fridges and aerosol cans. CFCs are incredibly stable in the atmosphere and are able to persist for years. This enables them to reach the stratosphere where they do their damage. During Antarctica's long winter months, the stratosphere's temperature plummets to less than -78 degrees Celsius (-108 degrees Fahrenheit), causing clouds of ice to form and trap chlorine-containing compounds. Once spring returns in September, the Sun's ultraviolet light frees the chlorine atoms into the stratosphere, starting a process that will result in the destruction of ozone molecules. A strong catalytic reaction takes place, enabling a single chlorine atom to destroy thousands of ozone molecules, as once the reaction is complete the chlorine is released unchanged, free to destroy even more ozone.

If the 1987 Montreal Protocol banning CFCs had not been introduced, it is thought that Antarctica's ozone hole would be 40 per cent larger and that another hole would have opened up. Fortunately, it has now stopped growing and is hoped to fully recover by 2070.

Ozone damage through the years

The growth of Antartica's ozone layer is clear to see in these yearly observations



First observations
The ozone hole was first measured by satellite in 1979 and from here on the extent of the damage was recorded in autumn each year, when the maximum damage is visible.

Ozone depletion
When scientists observed the ozone hole in 1980, they could clearly see that it had grown in size since the previous year.

Taking action
In 1987 the Montreal Protocol had been agreed upon by the UN; CFCs would be phased out.

No data
In 1995, there were no satellites in orbit that were able to collect the necessary data.

Continued depletion
Throughout the late 1990s and early 2000s, the ozone hole continued to grow, due to CFCs' ability to remain present in the stratosphere.

Unusually small
In 2002, the ozone layer was half the size it was in 2000. This was due to abnormally warm conditions in the stratosphere, rather than the ozone layer's recovery.

Peak size
In 2006 the ozone hole reached its largest recorded size; since then it has remained relatively stable.

Will it recover?
It is believed the ozone hole will eventually start to shrink in size. Levels of chlorine and bromine are continuing to reduce, which is an encouraging sign.

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The science behind your swing

Find out why tennis is such a difficult sport to perfect

Many sports scientists would argue that tennis is the toughest sport out there. It requires a mixture of speed, strength, endurance and mental fortitude, not to mention an abundance of talent if you plan on reaching the game's highest level.

Every professional strives to make perfect contact with the ball on each shot they hit. Scientists have proven that this is much harder to achieve than you might imagine, by calculating how far you would miss your target if you changed the racket angle by only one degree. It turns out that this tiny alteration would cause you to miss your target by an enormous 41 centimetres (16 inches). Further to this, they calculated that to make perfect contact you have a small window of only 0.6 thousandths of a second, presuming that the racket angle changes throughout the swing. This shows just how hard tennis is to master and why even the most seasoned professionals still need to practice for hours each day.

It's not just the players that affect the way a ball bounces and moves through the court, the court itself is also important. Tennis is played on a variety of contrasting surfaces, all of which affect a ball's trajectory and speed. A clay court will steal part of a shot's momentum due to the friction between the loose clay and the ball. This will slow down a 107.8-kilometre (67-mile) per hour shot by 43 per cent to only 61 kilometres (38 miles) per hour, giving the opponent extra time to return the shot. This differs to the grass courts of Wimbledon, which would maintain a speed of roughly 72.4 kilometres (45 miles) per hour for the same shot. Memories of this year's Wimbledon will now be starting to fade, but the tournament will have inspired many of us to perfect our swing in the hope of grass court glory.

Both the player and the court can alter the shot

Approximately five in every 1,000 people in the UK visit their GP about tennis elbow

Tennis elbow

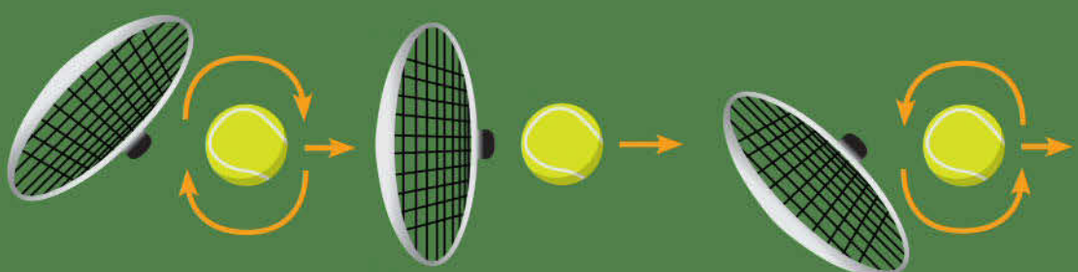
Technically referred to as lateral epicondylitis, tennis elbow is an injury that plagues many tennis players, leaving them unable to compete. It causes pain around the outside of the elbow, occurring when the forearm's muscles and tendons are strained as a result of repetitive or strenuous activity. Minute tears can form in the muscles surrounding the joint, causing it to become inflamed. This can result in a range of symptoms, varying from only mild discomfort when the elbow is in use, to severe pain even when resting the elbow. There is unfortunately no quick fix for this condition.

Tennis elbow can last for months or even longer, due to the slow speed at which tendons heal. The best treatment is to rest the elbow as much as possible and in 90 per cent of cases it will heal. Doctors may recommend physiotherapy or surgery for severe cases, however.

Secrets of spin

Modern professionals tend to be looking for more control rather than power in their game, and the key is to use topspin. This is achieved by the speed at which the racket is swung, the angle it connects with the ball, and the type of strings that are used. The polyester strings on modern rackets impart massive amounts of grip on the ball, acting almost like suction cups. This extra control enables players to generate large amounts of topspin: by brushing up the back of the ball with the strings causes the ball to rotate forward, which in turn creates an area of high pressure above the ball and low pressure below, so the ball dips sharply once the spin has taken effect. This means that players can hit the ball harder and still get it to land inside the lines. It will also give their opponents more problems as the ball bounces higher, making it harder to return.

Rafael Nadal is widely considered to be the king when it comes to generating topspin, having had some of his forehands recorded at an incredible 4,900 revolutions per minute (rpm). However, when it comes to backhand spin, Roger Federer is capable of generating a whopping 5,300 rpm!



TOPSPIN
This is the most commonly used type of spin, particularly prevalent in forehands, backhands and second serves. It causes the ball to jump up off the court, so that it bounces to an awkward height to return.

FLAT
Today, most professionals hit a flat first serve as this will enable them to hit with the most power. This is very effective on fast courts, as the ball will skid through quickly and take time away from the opponent.

SLICE
The main advantage of the slice technique is that it keeps the ball low. It works well on fast, low bouncing courts, forcing the opponent to bend down and return the shot from an uncomfortable angle.

Anatomy of the serve

Learn the biomechanics behind the most important shot in tennis

Many different things come together to produce the perfect serve including shoulder strength, wrist power and a knee bend

Racket-head speed

All of a tennis player's muscles work together to increase their racket-head speed, which is the speed at which their racket is propelled towards the ball.

Shoulder strength

The upper arm and shoulder provide only ten per cent of the racket-head speed, but are still vitally important. They help form what's known as the tick position which is the point just before the server swings the racket at the ball.

Forearm power

The forearm contributes 40 per cent of the total racket-head speed, the most out of any single body part. Experts recommend that the arm be fully extended at the point of contact, as this increases the overall length of the lever, providing the greatest possible speed.

Wrist snap

Immediately before contact is made, the wrist bends back away from the ball and then quickly 'snaps' forward, throwing the racket into the ball. This small movement provides 30 per cent of the racket-head speed, which is why a strong wrist is essential for all tennis players.

Knee bend

The legs and trunk provide 20 per cent of a serve's overall power. Some players use an exaggerated knee bend to help them spring up into the serve, which helps them make contact with the serve as high as possible. This provides them with a larger area to hit the serve into.

1 Stepping up to the line

The server places his leading foot close to the line, making sure not to touch it before making contact with the ball, as this would be considered a foot fault. His feet are spaced quite far apart, providing a wide base to push up from once the motion starts.

2 The toss

For fast serves, players throw their ball toss up to 60cm (24 inches) inside the baseline. This enables them to lean into the serve and generate power through weight transfer, as they uncoil upwards and forwards simultaneously.

Coiled trunk

The trunk uncoils after the hips, continuing the uncoiling process of the kinetic chain. A fast, powerful trunk rotation will translate into a more effective serve. Depending on the server's style, a large hip rotation can add considerable speed to their serve.

3 Tick position

Nearly all players adopt this position immediately before they contact the ball. Many players leave their non-dominant arm in a raised position to balance out the action of the racket arm, and also keep their torso raised which helps reduce the chance of serving the ball into the net.

4 The follow through

The forward motion generated by the serve will often cause the server's body to be thrown forwards so that they land inside the baseline. Hip rotation is an excellent source of power and we can see in this image that the server's body has turned to face the court after impact. His right leg extends backwards to provide balance and to enable him to quickly prepare for the next shot.

© Dreamstime; Thinkstock

What is anxiety?

How our brains trigger a fight or flight response

Anxiety affects a huge number of people and can be so severe that it stops many sufferers from leaving their homes or doing their jobs. In the US, over 40 million people aged 18 or over endure an anxiety related disorder, while in the UK one in 20 people are affected. Some researchers believe that modern day technology has influenced the rise of anxiety related conditions; we are constantly on high alert with texts, emails, social media and news updates.

Anxiety is a natural human response that serves a purpose. From a biological point of view, it functions to create a heightened sense of awareness, preparing us for potential threats. In a way, it's nature's panic button.

When we become anxious our fight or flight response is triggered, flooding our bodies with epinephrine (adrenaline), norepinephrine (noradrenaline) and cortisol, which help increase your reflexes and reaction speed. Your body prepares itself to deal with danger by increasing the heart rate, pumping more blood to the muscles and by getting the lungs to hyperventilate.

At the same time, the brain stops thinking about pleasurable things, making sure that all of its focus is on identifying potential threats. In extreme cases, the body will respond to anxiety by emptying the digestive tract by any means necessary, as this ensures that no energy is wasted on digestion.

Some people who suffer anxiety find it hard to leave the house

How your brain reacts

The body's primal response to danger can be triggered by non-threatening situations

Cortex

Once the amygdala and hippocampus have received a stimulus, the cortex's role is to find out what's caused the fear response. Once the perceived danger is over, a section of the prefrontal cortex signals the amygdala to cease its activity. It is vital to turning off anxiety.

Thalamus

Visual and auditory stimuli are first processed by the thalamus which filters the incoming information and sends it to the areas where it can be interpreted.

Locus caeruleus

This area of the brain stem is triggered by the amygdala to initiate the physiological responses to anxiety or stress, such as an increase in heart rate and pupil dilation.

Two paths

A startling signal such as a sudden loud noise will be sent from the thalamus via two paths: one travels directly to the amygdala - where it can quickly initiate the fear response - and the other passes through the cortex to be processed more thoroughly.

Hippocampus

The hippocampus is the brain's memory centre, responsible for encoding any threatening events that we experience in life into long-term memories.

Stria terminalis

The bed nucleus of the stria terminalis (BNST) is responsible for maintaining fear once this emotion has been stimulated by the amygdala, leading to longer-term feelings of anxiety.

Amygdala

This is where the fear response is triggered. The amygdala can quickly put your body on high alert, and research suggests that if this area of the brain is overactive, it may cause an anxiety disorder.

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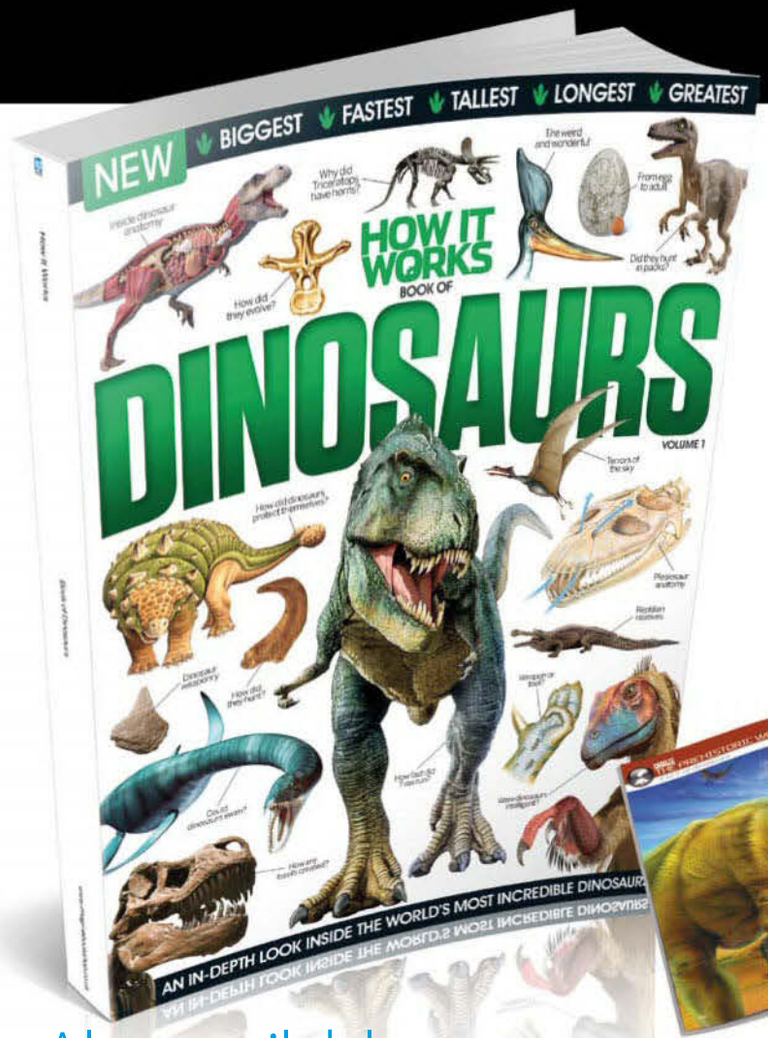
From the makers of HOW IT WORKS



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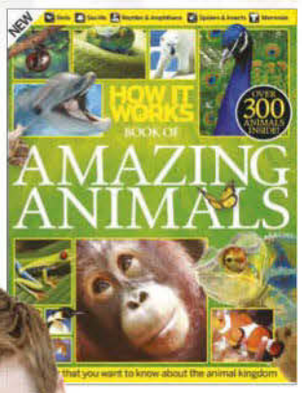

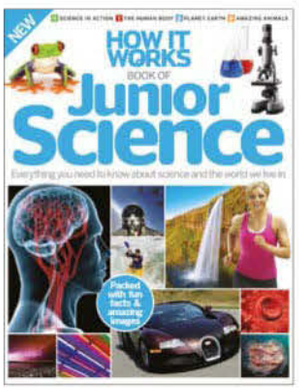

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Watch and subscribe to our videos on YouTube! **www.youtube.com/howitworksmag**

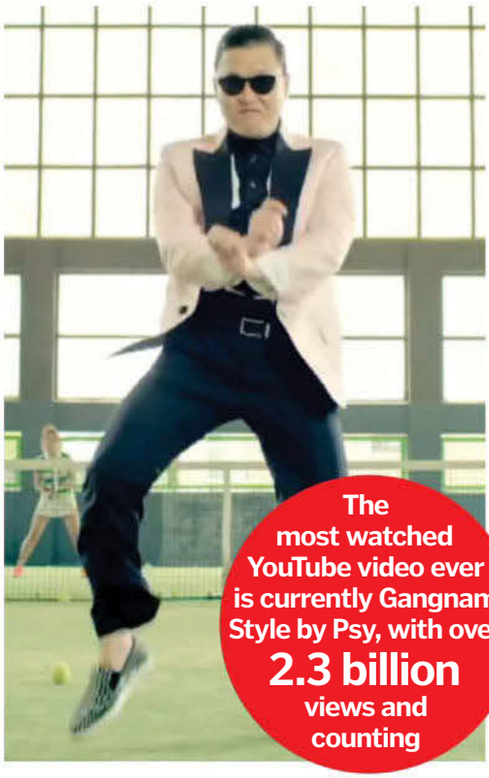
Since it first launched in 2005, YouTube has quickly become the number one destination for video content online, attracting over one billion regular users. The Google-owned site gained popularity by enabling people to share their videos with others all over the world, whether it's an amusing clip of their pet,or footage of them dancing in their living room.

It's not all about cute cat videos and funny home movies though, as YouTube has also helped people launch careers. For example, pop star Justin Bieber was first discovered when a talent scout saw videos of him singing on the site, and Zoe Sugg, aka Zoella, has got her own book deal and range of beauty products as a result of her popular video blog, or 'vlog'. You can even earn money directly from YouTube too, as the site shares some of the revenue it makes from companies who pay to run adverts before or over your video.

The popularity of YouTube is mainly down to how easy the website is to use. Videos in a range of file formats can be uploaded as YouTube converts it into its Adobe Flash video format, with the file extension .FLV, for you. This enables the video to be played using YouTube's Flash player, which can be installed on your computer or smart device for free.

Another benefit of YouTube is the ability to embed videos on other websites. By simply copying and pasting a bit of HTML code, you can enable people to watch a video on your own website using the YouTube player. This saves you having to host the video on your site which requires a lot of bandwidth. Bandwidth is the range of signal frequencies needed to transmit data over the internet and you have to pay for ▶

"The popularity of YouTube is mainly down to how easy the website is to use. Videos in a range of file formats can be uploaded"



The most watched YouTube video ever is currently Gangnam Style by Psy, with over 2.3 billion views and counting

YouTube sensation Zoe Sugg, aka Zoella, films her beauty videos in her bedroom

Going viral

How to become a YouTube celebrity

1 Find your niche
Choose a topic or theme for your YouTube channel that's interesting and or entertaining, and hasn't been done before. For example, YouTube celebrity Zoella gives fashion and beauty tips and reviews her favourite products.

2 Create a studio
You could film your video using your smartphone, but for a more professional look, set up a camera on a tripod. Either make use of the natural light by shooting outdoors or in a well-lit room, or you can set up your own lighting.

3 Upload your video
Finish off your video using editing software, cutting out unnecessary footage and making sure the audio can be heard. Now create a YouTube account and upload your video. The site will automatically convert it into the correct Adobe Flash video format for you.

4 Give it a title
When naming your video, make sure you include any keywords relating to the topic featured and think about what sort of terms people might search for to find it. Also give it an appropriate thumbnail image and a comprehensive description.

the amount you use. YouTube streams vast amounts of data each day, carrying the bandwidth burden for other sites that want to display video.

Although embedding is great for spreading your videos further across the internet, most people will actually find them simply by searching. To help connect users to the videos they are looking for, YouTube uses a complex algorithm made up of over one million lines of code. When you search for a video, the algorithm decides which search results it will show you and in what order. One of the main factors used to rank the results is video metadata. This is the title, description, thumbnail and tags that you give your video when you upload it, so you should make sure they are relevant to the content of the video and what people might search for to find it. However, the other ranking methods YouTube uses are out of your control. The site used to rank its videos by how many times they had been viewed, but this presented a few problems. It often meant that new videos were pushed to the bottom of the list as their view counts had not yet had a chance to grow, and it also enabled people to manipulate their ranking by clicking on their video repeatedly, as clicking the play icon counts as a view. To combat these problems, YouTube has switched to a new system of measuring a video's quality by the length of time it has been watched for. If several users have stopped watching after a few seconds, this suggests that the video had a misleading title or thumbnail and didn't give viewers what they were looking for, whereas if they stayed to watch until the end it was most likely appropriate for the search terms used and therefore worthy of a high ranking. The rest of YouTube's ranking tricks are a mystery though, as the company is very secretive about its algorithm and changes it all the time to stop people manipulating it. What we do know, however, is that YouTube does take some steps to ensure a video's view count indicates it's quality and this is highlighted by the mysterious number 301. You may have noticed, that as a video's view count climbs, it quite often pauses at this number for a few hours or even days. This is because when a video reaches just over 300 views, a team of YouTube employees has to verify that the number accurately represents the popularity of the video. They do this by analysing the viewing statistics to make sure people are watching the video all the way through and not just clicking play to raise the count. While they do this, the view count is frozen at 301 until it has been confirmed as genuine.

Over 500 years of YouTube videos are watched on Facebook every day

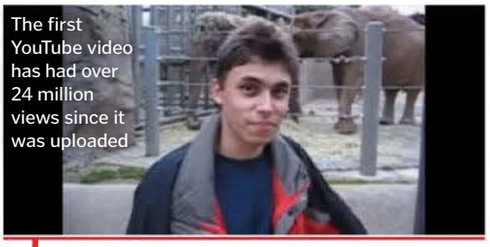
Video storage

Every video uploaded to YouTube is stored in at least one of Google's 14 data centres spread across the world. These enormous buildings contain thousands of servers – the powerful computers that handle the billions of Google searches made every day and also store your videos. Giant cooling towers keep the temperature inside at a steady 27 degrees Celsius (80 degrees Fahrenheit) to ensure the equipment runs smoothly, and each piece of data is stored on at least two servers for extra security. The data centres can also communicate with each other to send information between them. When you upload your video it will be stored at the data centre nearest you, but when someone wants to play it, the video will be sent to their nearest data centre for quick access. This also means that in the event of a fire or other disaster, the data is sent to another data centre so that it's always accessible.

Google data centres can be found in Europe, Asia and North and South America

"The site used to rank its videos by how many times they had been viewed, but this presented a few problems"

A brief history of YouTube



The first YouTube video has had over 24 million views since it was uploaded

YouTube was one of the original applications on the iPhone

2005
The first YouTube video was uploaded by the site's co-founder Jawed Karim. It's an 18 second clip of him at the zoo.

2006
Google buys YouTube for £883 million ($1.65 billion) in shares. The site now has around 72 million visitors each month.

2007
YouTube Mobile is launched enabling people to watch videos on their smartphones, and the site begins showing adverts.

2008
720p HD support is added, enabling high definition videos to be uploaded and viewed widely for the very first time.

The journey of a YouTube video

What happens to your video once it has been uploaded?

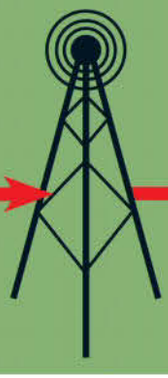
1 billion people regularly use YouTube to watch and upload videos

Uploading

1 Uploading
Once you hit Upload, YouTube copies your video into several different file formats with differing levels of video quality.

2 Video packets
Each version of the video is then chopped up into several different pieces called packets.

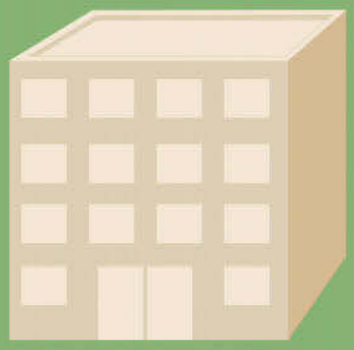
3 Wireless transmission
The packets are then encoded as radio waves which are sent over Wi-Fi or a mobile network.



4 Delivered to YouTube
When the signal reaches a cell tower or router, it is transmitted via a wired connection to YouTube's servers.

300 hours of video are uploaded to YouTube every minute

5 Reassembly and storage
YouTube's servers receive the packets, reassemble them into a video and store it at Google's data centres.



Downloading

1 Click play
When someone clicks to play your video, a request is sent over the internet to YouTube's servers.

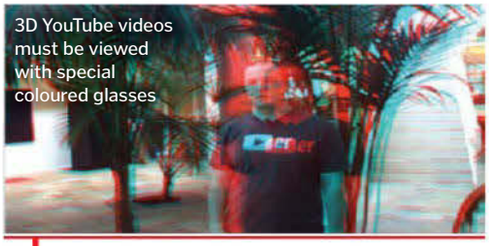
2 Video chopped up
YouTube selects the best video format for the browser being used to view it and chops it back into packets.

Over **700** YouTube videos are shared on Twitter each minute

3 Delivered to the viewer
The packets are sent via wired and wireless connections to the viewer's computer.

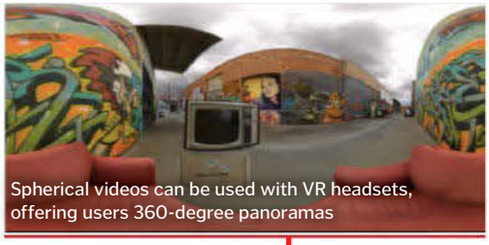
4 Instant playback
The packets are delivered in order to form the original video at the optimum quality.

5 Buffering
If the internet connection is slow, the video may buffer when waiting for the next packet to be delivered.



3D YouTube videos must be viewed with special coloured glasses

The live streaming service enables people all over the world to watch events as they happen



Spherical videos can be used with VR headsets, offering users 360-degree panoramas

2009
Users can now upload and view up to 1080p HD footage. Support for 3D videos is also added for a better viewing experience.

2010
YouTube keeps up with technology and includes support for ultra-high definition 4K videos to be uploaded to the site.

2011
YouTube's Sliced Bread project enables videos to be sent to your device a little bit at a time to help prevent buffering.

2012
The live streaming service is improved, enabling over 1,200 events during the London 2012 Olympics to be watched live.

2014
Support for videos that play at 60 frames per second (fps) is added, which provides much smoother playback.

2015
Spherical videos can now be uploaded, enabling the viewer to see a scene from absolutely any angle of their choice.

© Rex Features; Thinkstock

Underground engineering

Find out how New York City's subway was constructed more than 100 years ago

Underneath the city's pop-up-book skyline, lies a sprawling subway system. Transporting nearly two billion passengers annually, it operates 365 days a year, 24/7, on over 1,287 kilometres (800 miles) of track, connecting all the boroughs of New York, except Staten Island.

During the late 19th century, New York experienced a population boom due to the huge numbers of immigrants that arrived from Europe, meaning that almost 3.5 million people were living there by 1900. This placed enormous strain on the existing transport systems; roads were more congested and travel became increasingly difficult and dangerous. The authorities realised they needed a subway that could quickly and efficiently move people in, out and around Manhattan.

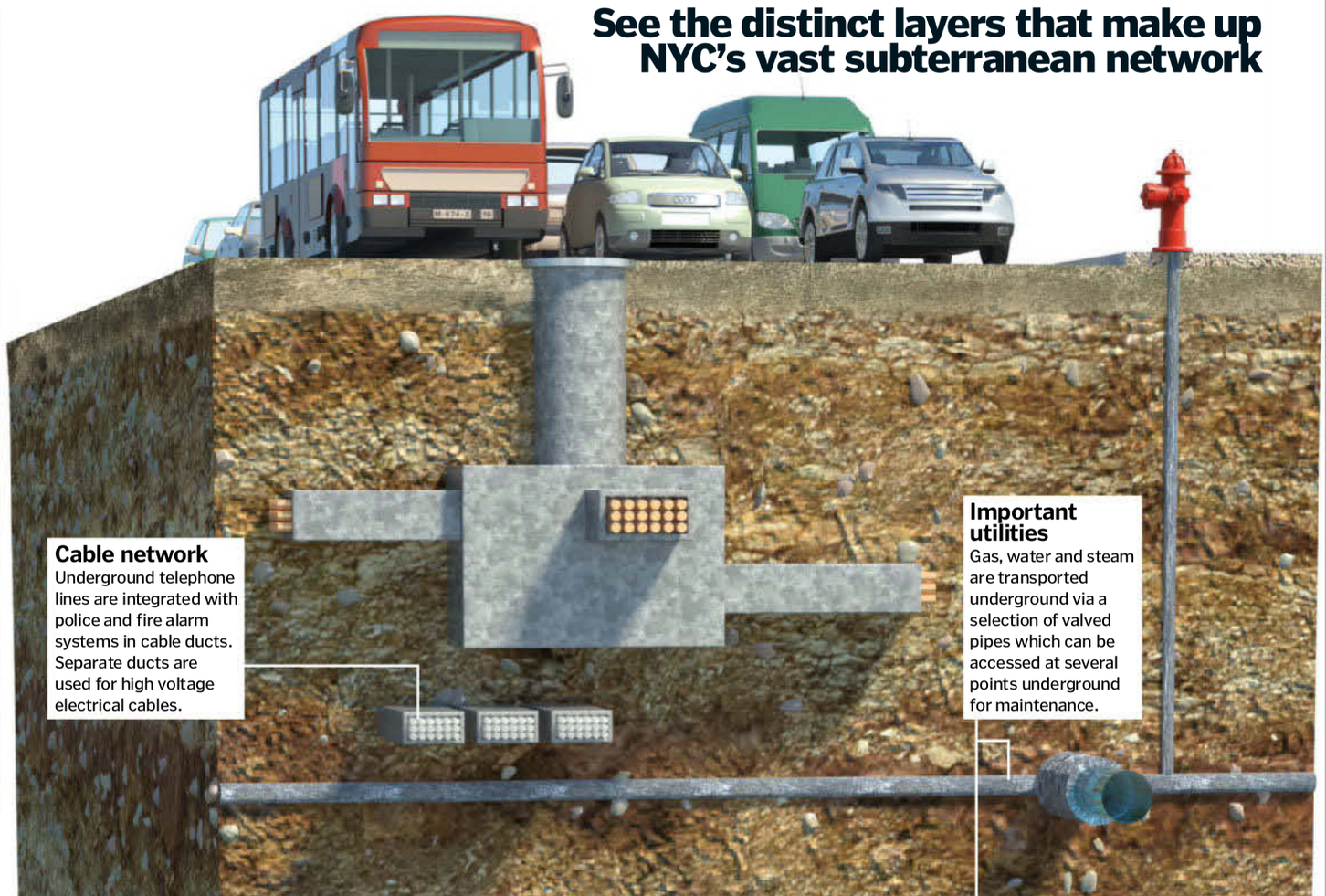
The construction of the first subway line began in 1900. Engineers of the time had to take into account various challenges such as uneven topography, hard bedrock and the sheer number of water, sewage and gas pipes that already lay underground. The project was no mean feat – around 8,000 labourers were employed to excavate the subways, thousands of which sustained injuries and more than 40 lost their lives.

For shallower tunnels, the engineers often preferred to dig down from the road surface, as this made it easier to avoid the utilities that were already buried below. They could then replace the pipes above the subway, modifying their design if necessary, and reconstruct the road surface.

For deeper tunnels, engineers used powerful explosives that were more efficient than digging by hand, but did result in a number of casualties. A variety of techniques were used to overcome some of the installation problems, such as passing the tunnel through a river. To build some of the underwater subway areas, engineers cleverly constructed the tunnel sections above ground and then sunk them into a dredged part of the river, before pumping the water out.

The construction of Second Avenue's subway, which began in 2007

See the distinct layers that make up NYC's vast subterranean network



Cable network
Underground telephone lines are integrated with police and fire alarm systems in cable ducts. Separate ducts are used for high voltage electrical cables.

Important utilities
Gas, water and steam are transported underground via a selection of valved pipes which can be accessed at several points underground for maintenance.

Expanding the subway system

The New York City underground system is now over 100 years old. It wasn't designed to accommodate the enormous numbers of people that use it daily, so the decision was made to expand it. The plan is to add around 34 kilometres (21 miles) of new tunnel throughout the city, via the East Side Access, Second Avenue Subway, and the 7 Line Extension projects, which are estimated to cost over £9.6 billion ($15 billion).

Engineers would normally use a single tunnel boring machine (TBM) to create the new tunnels. However, in the case of the East Side Access project, such a large tunnel would collapse under the weight of the city above it. This problem has led the designers to employ a slightly unusual technique. Using four smaller TBMs, they will produce four more stable tunnels, which will then be fused to form one larger tunnel. This is accomplished using dynamite to blow out the rock between the small tunnels. Firstly, the top two small tunnels are fused, at which point the roof of the tunnel is reinforced to stop the underground network above collapsing downwards. Once the roof has been strengthened, the remaining two tunnels are joined to create a single tunnel. Work is scheduled for completion in 2022.

© Thinkstock; Alamy

Steel piles
Groups of steel piles were driven into the surrounding bedrock to provide structural support. They were capped with concrete once put in place.

Subways
Most of New York's famous subway tunnels were constructed within 15.2m (50ft) of the surface, but some go much deeper.

Forgotten pipes
A number of utility pipes still lie below the subway, but they aren't used anymore because they are difficult to access.

Sewage system
The combined line for sewage and storm water was laid on a slope, enabling it to flow by gravity to a number of treatment plants.

DID YOU KNOW? *If all the tracks in the NYC subway were laid end to end, they would reach Chicago*

How Google Cardboard works

Turn your smartphone into a virtual reality headset with a cardboard box, a magnet and some Velcro!

Google's Cardboard venture has opened up the world of virtual reality to everyone. To whisk us away into a fantasy world, Google invites us to make our own VR headset using just a few items that can be found in your garage.

Various cardboard headsets can also be purchased ready-made, so it's not all about DIY. Once you've sourced the headgear, all you need to do is download the Google Cardboard app to get started.

Your smartphone sits in the headset and the app shows you a specially designed split-screen view. When you look at the screen through the headset's lenses that are placed at an optimum distance from the screen, this concentrates your field of view and creates a 3D effect. Your smartphone's motion sensor detects your movement and so all of these factors come together to enable you to walk, run and jump through your own virtual world.

Google has made this technology incredibly accessible for developers, so there is also a huge array of compatible VR apps available to take your Cardboard experience to the next level.

The Cardboard experience

The little brown box that's putting a whole world of virtual reality at your fingertips

Lenses
Two lenses focus your vision and enable you to see and even move around 3D images.

Magnet
You can't touch your phone in the headset, so this magnet acts as a button!

Smartphone
Cardboard is now available for both Apple and Android operating systems.

Cardboard App
Begin with the Cardboard app, then download other compatible ones and lose yourself in VR.

NFC chip
This chip automatically launches the app when the smartphone enters the headset.

How an icebox cools your food

These portable chillers save us all from wilting sandwiches at a picnic, but how do they work?

Iceboxes are usually rather ugly looking things made out of bulky plastic with a thick lid. But attractive aesthetics are sacrificed for good reason – the name of the game here is insulation. The walls of an icebox consist of multiple layers, filled with an insulating material such as polystyrene that is full of air pockets. Air is a poor conductor of heat, so the gaps in the foam help to slow down the energy transfer of heat from the outside to the inside of the box.

Heat is transferred in three different ways: convection (heat moving through fluids – liquids or gases), conduction (heat moves through a substance by particles colliding), and radiation (heat is given off and absorbed by an object via electromagnetic waves). When cold food is placed into the icebox and the lid is shut, very little heat can reach the food via convection because warm air from the outside cannot pass through the box. Conduction is also poor because the air bubbles in the polystyrene layer are good insulators. Some iceboxes or cool bags also have a reflective outer coating to deflect radiation, such as sunlight, away from the precious picnic cargo.

© Corbis; Alamy

The world's longest man-made waves

Deep in north Wales' Conwy Valley, a giant underwater snowplough is rolling out some serious swell

Wave hunters – rejoice! In an old aluminium quarry in north Wales, an inland surf facility is edging ever closer to completion and when it opens, surfers from across the globe can visit to ride the world's longest man-made waves.

Surf Snowdonia is a £12 million ($18.7 million) project built by surfers, for surfers. The engineers of Wavegarden are keen wave riders, and wanted to create something remarkable that can help existing surfers to train and budding wave riders to learn, without having to wait for unpredictable waves at the coast.

The technology that can create these waves looks a lot like a giant snowplough. It is pulled smoothly along underwater (with a protective covering to keep surfers safe) through the centre of the 300 metre (984 foot) long lagoon, pushing the water ahead of it into large, tubing waves that the designers claim are just like, if not better than, shredding the real thing. At their highest point the waves can reach two metres (6.6 feet) high and peel for 150 metres (492 feet), which is the equivalent of a 20-second ride for the surfer.

At a rate of one wave generated every minute, the waves that are created by the expertly engineered snowplough-like wave foil also interact with the contours on the bed of the lagoon. This provides different and predictable wave profiles at various points of the pool, meaning that there's a place at the lagoon for surfers of every age and ability.

Surfer Miguel Pupo rides the man-made waves at a Wavegarden test facility in Spain

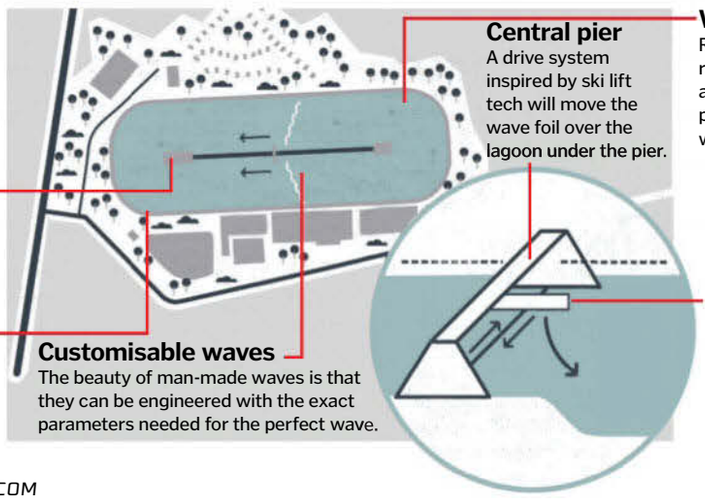
Wave machine vs ocean waves

Most ocean waves begin out at sea and are a product of the wind blowing over the water's surface. This causes friction and as the wind continues to blow, the wave builds and builds. A 'singular' wave extends vertically down the water column and so as it approaches the shore, the shallow water causes drag on the 'base' of the wave. This causes the wavelength to shorten, which forces the crest of the wave higher until it eventually spills over itself and breaks, like the waves we see crashing on the shore.

The difference between these waves and those at Wavegarden's Surf Snowdonia is that the man-made waves don't have the wind to whip them up, nor miles of ocean to grow in size and power. Instead, the wave foil smoothly 'shovels' the water in front of it, pushing it upward and ahead, mimicking the very last stages of a breaking ocean wave on the shore.

Totally tubular tech!

A tour of the artificial surfing lagoon that creates consistent and perfectly-formed waves



Computer tech
At each the end of central pier, towers house the computer-based technology that controls the wave foil.

Lagoon lining
The unique grid-like shore lining of the lagoon is designed to dissipate the energy created by the waves.

Central pier
A drive system inspired by ski lift tech will move the wave foil over the lagoon under the pier.

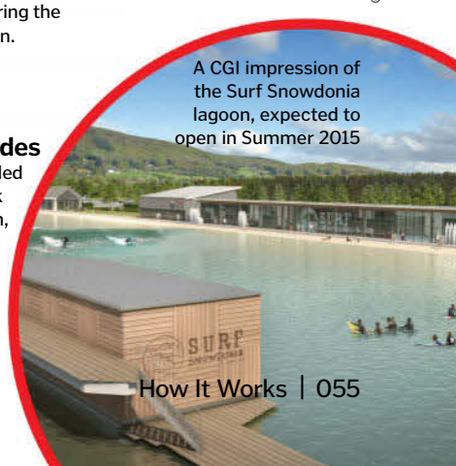
Customisable waves
The beauty of man-made waves is that they can be engineered with the exact parameters needed for the perfect wave.

Water supply
Rainwater from mountain reservoirs will pass through a nearby hydroelectric plant before powering the waves in the lagoon.

Reversible rides
The plough is pulled forward and back across the lagoon, so surfers are able to ride waves in both directions.

Surfers galore
Up to 52 surfers at a time will be able to ride the waves in the lagoon.

© Wavegarden



A CGI impression of the Surf Snowdonia lagoon, expected to open in Summer 2015

The future of commuting

Explore the cutting-edge technology set to change the way we travel

How long do you spend commuting every day? The average journey time is a soul-sucking 60 minutes, which amounts to over a year of our lives travelling to and from work. Whether it's via road, train or even sky, the commuter experience is blighted by traffic and human or technological errors, leading to delays and expensive fares to supplement archaic modes of transport.

However, the daily slog could be about to change for the better. Thanks to a raft of new technology, we'll see vast improvements to the speed and safety of a commute over the next 50 to 100 years, through improving current transit systems and implementing entirely new modes of transport in the future. These range from faster, more efficient bus services, to sophisticated capsule-based transport that will turn a three-hour journey into a thirty-minute intercity blast.

The future of commuting will also benefit the environment thanks to the development of cleaner, greener vehicles. Electric and hybrid engines are an increasingly popular choice in passenger cars, and the technology is transcending into other forms of transport including motorbikes, buses and even helicopters. This means we'll be producing fewer emissions on our journey to work and we won't be relying on the Earth's diminishing supply of oil to power our various forms of transport. In fact, some forms of transport are likely to produce more energy than they actually use!

Of course, electricity isn't the only source powering commuter vehicles both now and in the future. Innovative forms of travel include linear electric motors for Elon Musk's Hyperloop and maglev technology for Israel's skyTran. We also can't forget the 'number two' Bio-Bus in the UK that's currently transporting passengers between the cities of Bath and Bristol, thanks to the biomethane gas produced from human waste!

No matter what way you look at it, the international workforce of the future has little to fear. They'll be able to relax, sipping coffee as their autonomous car does all the steering, or reclining in a levitating pod that soars above the city. Over the next few pages, take a glimpse into the exciting future of travel but in the meantime, always remember to mind the gap between the train and platform edge!

Building better buses

Bus rapid transit, or BRT, is billed as the future of urban transport. The system aims to efficiently ferry passengers around busy urban environments in a cost-effective way, and BRT vehicles travel on dedicated bus-only lanes that are segregated from regular vehicle carriageways, reducing delays due to traffic. All bus stop platforms are at the same height as the floor of the bus for easy access for wheelchair and pram users, and passengers pre-pay for the bus electronically; significantly reducing the amount of time a bus remains stationary at stops. This means BRT can provide a speedier service, ensuring commuters spend less time in the place they don't want to be – the bus.

Signal priority
Some rapid bus systems use signal priority transmitters to hold a green light long enough for the bus to get through an intersection.

Bus stop platform
These are the same level as the bus floor, making it easier for passengers to get on and off.

New and improved Underground systems

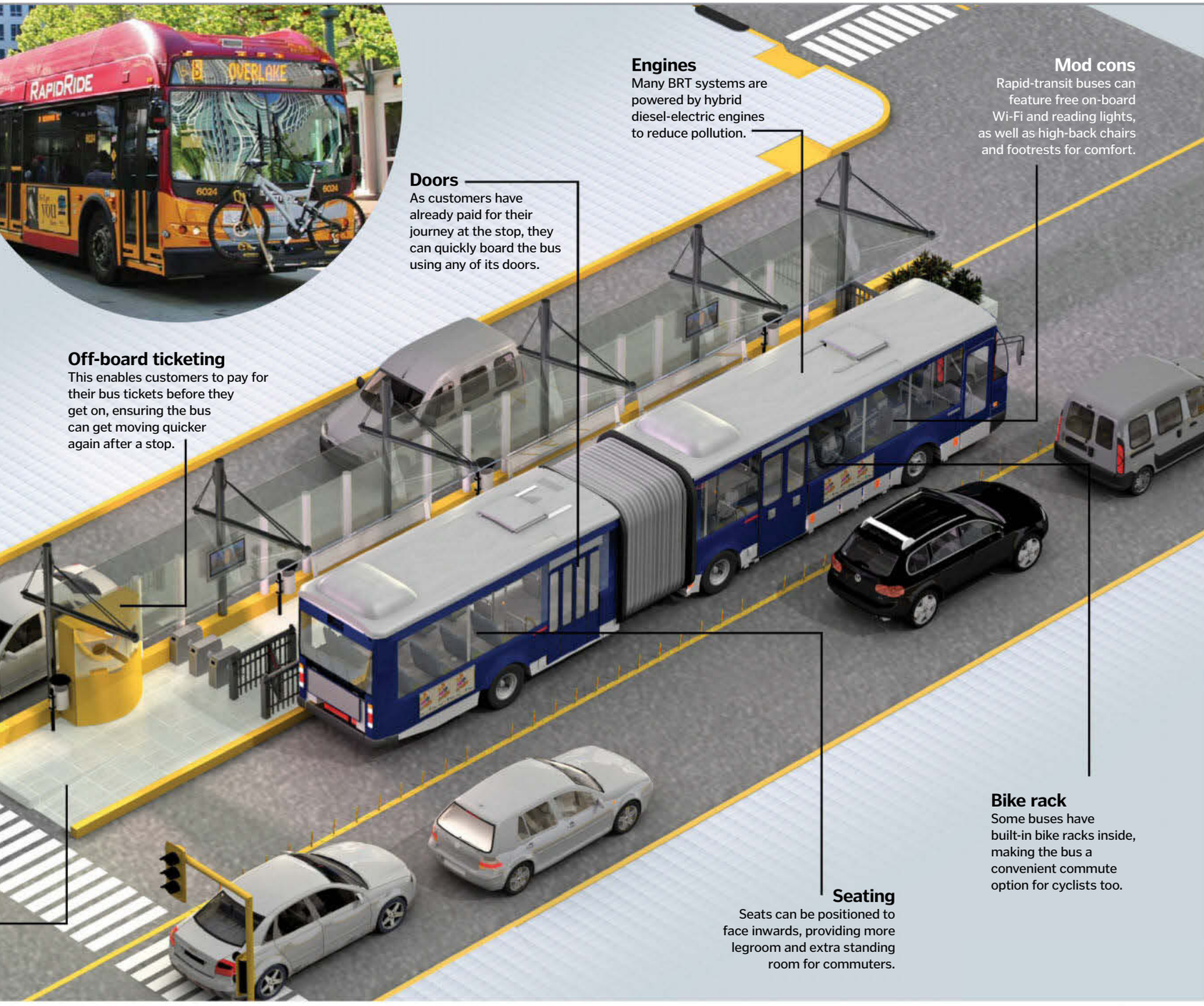
The London Underground is a vital transport network for Britain's capital city, and Transport for London has plans in place to improve the services and travel experience for its customers. All-new trains are being rolled out on the Piccadilly Line, with the Bakerloo, Central, and Waterloo & City lines following shortly after. The new trains will be air conditioned to make journeys more comfortable, with walk-through carriages to allow for extra room during peak periods of travel. The lines' signalling systems will also be upgraded, helping to eliminate delays. and this September will see the introduction of a 24-hour service for central London stations.

The new train design for London promises to deliver faster, more frequent journeys

Driverless pods

These small electric vehicles call on the same technology piloted by other driverless car projects, using sensors, lidar and navigation equipment to transport one or two passengers autonomously to their destination via road or pavement. Think this is a technological advancement of the future? Think again. Driverless pods are already being trialled in several UK towns and cities including Oxford and Milton Keynes.

Driverless pods are currently spearheading the automotive industry's autonomous vehicle push



Engines
Many BRT systems are powered by hybrid diesel-electric engines to reduce pollution.

Mod cons
Rapid-transit buses can feature free on-board Wi-Fi and reading lights, as well as high-back chairs and footrests for comfort.

Doors
As customers have already paid for their journey at the stop, they can quickly board the bus using any of its doors.

Off-board ticketing
This enables customers to pay for their bus tickets before they get on, ensuring the bus can get moving quicker again after a stop.

Bike rack
Some buses have built-in bike racks inside, making the bus a convenient commute option for cyclists too.

Seating
Seats can be positioned to face inwards, providing more legroom and extra standing room for commuters.

Zero emission motorbikes

They're an ideal form of transport to zip one or two people at a time through busy city streets, but internal combustion-engine motorcycles are still damaging the environment in the same way cars do. However, with electric car sales on the rise, the same technology is being applied to their two-wheeled counterparts with the introduction of eco-friendly electric motorbikes. Some models can offer an impressive range of up to 300 kilometres (185 miles) per charge, which is ample for cutting through traffic-laden city streets.

© Transport for London; Solgo

The Hyperloop

Elon Musk's fascination with revolutionising the way we travel doesn't just include the electric Tesla road vehicle or SpaceX rockets. The entrepreneur's most innovative idea yet focuses on a high-speed super shuttle called the Hyperloop. This *Futurama*-style tube concept is billed as a high-speed transport system for both people and cargo, capable of whizzing between San Francisco to Los Angeles – a total distance of around 600 kilometres (372 miles) – in just 35 minutes.

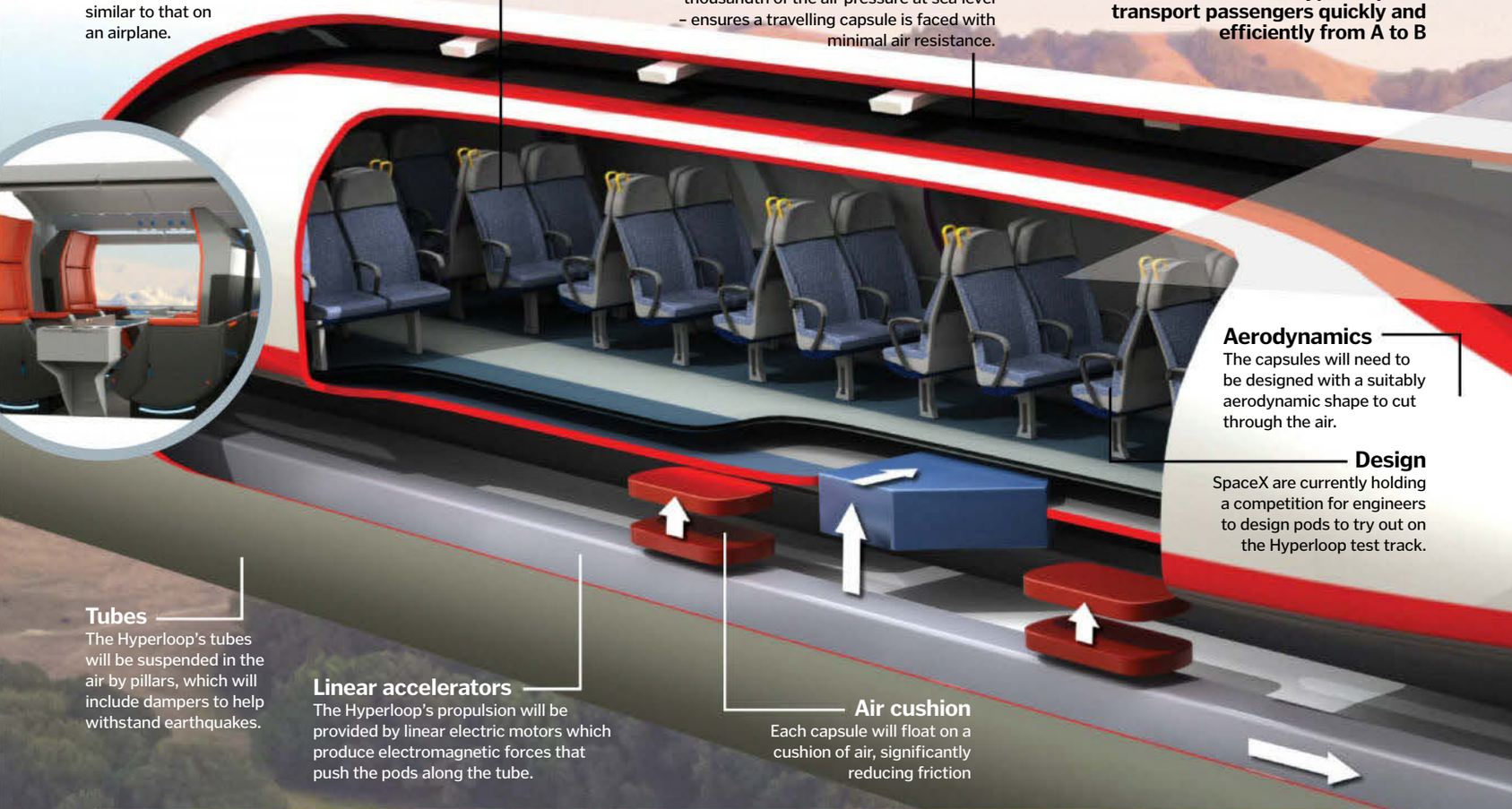
This unconventional design involves pods travelling through a tube at almost the speed of sound. To achieve such an incredibly quick journey between the two Californian cities, the Hyperloop's tubes will be depressurised to significantly reduce atmospheric drag on the pods as they zip through. Musk ruled out using a complete vacuum, however, since this would be difficult to maintain and even so much as a tiny crack in the tube would completely stop the whole system working.

The pods will have aluminium ski-like fixtures that will have high-pressure air pumped through them, allowing the capsules to levitate on a cushion of air, similar to an air hockey table. These skis will pass through tracks of linear induction motors positioned throughout the tube which will electromagnetically accelerate or decelerate the pods as required.

An eight-kilometre (five-mile) test track of the Hyperloop system is due to be built in California next year. If the project is a success, we could soon see a super-quick form of transport for people and goods that doesn't cost lots to run, making Hyperloop one of the most exciting advancements to ever occur in the travel industry.

Inside the Hyperloop

Here's how Elon Musk's Hyperloop will transport passengers quickly and efficiently from A to B



Passengers
Each capsule should be able to hold 28 passengers, with seating similar to that on an airplane.

Tube pressure
Reduced pressure – approximately one thousandth of the air pressure at sea level – ensures a travelling capsule is faced with minimal air resistance.

Aerodynamics
The capsules will need to be designed with a suitably aerodynamic shape to cut through the air.

Design
SpaceX are currently holding a competition for engineers to design pods to try out on the Hyperloop test track.

Tubes
The Hyperloop's tubes will be suspended in the air by pillars, which will include dampers to help withstand earthquakes.

Linear accelerators
The Hyperloop's propulsion will be provided by linear electric motors which produce electromagnetic forces that push the pods along the tube.

Air cushion
Each capsule will float on a cushion of air, significantly reducing friction

A taxi service in the sky

Personal helicopters aren't the only next-gen form of travel whisking passengers away from street level. SkyTran, which has a pilot project currently in development in Israel, is a monorail-like system with pods suspended six to nine metres (20 to 30 feet) above the ground and provides high-speed, low-cost transport for its users. Passengers simply summon a pod to a station via an app on their smartphone and it takes them where they want to go. The system works using maglev technology which utilises magnets in the rail to levitate the two-person pods so they are not in direct contact with the track, reducing friction. The cutting-edge technology, developed with NASA's Ames Research Center, means that the pods generate their own levitation as they move, only requiring an initial burst of power to start and stop. A 500-metre (1,640-foot) test track will be built at the campus of Israel Autospace Industries, where the pods will be able to reach speeds of up to 70 kilometres (43.5 miles) per hour. If the trial is successful, this all-new form of transport will be installed in the heart of Tel Aviv, before being introduced to cities across the world.

SkyTran's pilot project will demonstrate a network of high-speed, low-cost transport

Personal helicopters

Traffic is swelling on roads around the world and in Brazil the wealthy are looking to avoid this altogether – by taking to the skies in personal helicopters. As such, novel designs such as the Volocopter are becoming increasingly popular among the urban elite. Key to the success of vehicles like the manned Volocopter, which can carry up to two passengers at a time, is that they are capable of a vertical take-off or landing, making it very useful in tightly packed cities where space is at a premium. The Volocopter is powered by electric motors, making it quieter and more environmentally friendly than a conventional helicopter. The lack of an internal combustion engine also eliminates the vibrations and the high noise level associated with helicopters, meaning the Volocopter is much more comfortable for its occupants.

German company e-volo's Volocopter is an electrically powered VTOL aircraft

Solar power
The Hyperloop looks set to harness the Sun's energy by installing solar panels along the roof of the tube.

Speed
The capsules will whiz through the Hyperloop at a top speed of about 1,223km/h (760mph) – just below the speed of sound.

Air compressor
A large compressor fan will be mounted to the front of each capsule to help direct air toward the back and out of the pod's path.

Journey times from LA to San Francisco

© Thinkstock; Argodesign

The ultimate cruise

Discover the amazing tech on board the latest colossal cruise ships

Cruise ships are getting bigger and bigger, with the latest vast vessels able to transport the entire population of a small town to new and exciting destinations. Cruise line Royal Caribbean International is leading the way when it comes to building the world's largest floating hotels, with their Allure of the Seas and Oasis of the Seas ships taking the top two spots. However, as well as making their ships bigger, they are also striving to make them smarter, with their latest vessels featuring state-of-the-art technology to enhance the cruising experience. The Quantum of the Seas and its sister ship the Anthem of the Seas may 'only' be the joint-third largest in the world, but it's the gadgets and gizmos on board that set them apart from the rest. With robotic bartenders, virtual balconies and a whole host of interactive art on board, these cruise ships offer the ideal holiday for tech fans.

Learn to surf or bodyboard on the ship's top deck

92m (300ft) high

The North Star viewing capsule can put you at eye-level with the Statue of Liberty

This ship is as long as five Boeing 747 jets

347.8m (1,141ft) long

1 Roboscreens

The large venue at the back of the ship is called Two70°, because its floor-to-ceiling glass walls offer 270-degree panoramic views. However, at night, the space is transformed as 18 projectors cast 12K resolution scenes onto the windows. Six 2.5-metre (eight-foot) 'Roboscreens' can also be choreographed to move independently or in unison to enhance the evening's shows.

2 Surf simulator

Test your surfing skills on board the ship with the FlowRider surfing simulator. This powerful machine pumps out 272,800 litres (72,057 gallons) of water per minute at speeds of 48-64 kilometres (35-40 miles) per hour, creating a smooth wave that you can surf or bodyboard, even when the surrounding ocean is as calm as a pond.

3 Skydiving simulator

The first skydiving simulator at sea enables you to experience freefall without having to jump out of a plane. The seven-metre (23-foot) tall vertical wind tunnel contains a fan capable of generating windspeeds of around 209-282 kilometres (130-175 miles) per hour, creating a cushion of air on which you can float.

4 App planner

When you climb on board, the free Royal iQ app enables you to track your luggage, so you know when it has been delivered to your cabin. It works by tracking the RFID (radio-frequency identification) tag on your bag, which uses electromagnetic fields to transmit data about your luggage's current location. The app also provides information about what activities you can do both on and off the ship.

The North Star can carry 14 guests up and over the side of the ship

4,694bhp

The ship's four bow thrusters each produce the equivalent horsepower of six Formula One cars

Cameras mounted around the ship capture the view, which is live-streamed to the virtual balconies

"State-of-the-art technology enhances the cruising experience"

40.7km/h (25mph)

It can reach a cruising speed of 22 knots, beating Usain Bolt's average speed

5 Connectivity
Stay in touch with your friends and family back home with the super-fast internet on board. Satellites launched by tech company O3b Networks beam signals directly to the ship, delivering more bandwidth to the Quantum-class vessels than all the other cruise ship in the world combined. This enables you to upload photos, stream video and even compete with gamers all over the world in the Xbox Live suite.

6 Robot bar
Human bartenders have been replaced by robots at the high-tech Bionic Bar. You order your drink via an app on a tablet, choosing from the menu or creating your own concoction from a long list of ingredients. One of the two robot arms will then mix your drink, mimicking a human bartender's action to shake, stir or strain it.

7 Viewing capsule
You can get a breathtaking bird's-eye view of the ship and its surroundings by boarding the North Star viewing capsule. The glass pod is located on the end of a long arm fixed to the top deck. It can lift you 91 metres (300 feet) above sea level to give you a 360-degree view while at sea or in port.

8 Virtual balconies
Even if you can't afford to upgrade to an outside cabin with a balcony, you can still experience stunning views from your room. The interior cabins feature virtual balconies, using two-metre (80-inch) high-definition 4K LED screens to display the sights and sounds of the outside world in real-time.

© Royal Caribbean

The science of racing simulators

Almost as good as the real thing, these high-tech simulators are an invaluable training tool for a racing driver

We have all played on driving simulators in arcades or on games consoles at home, but what was once a bit of fun is now a serious business – and a crucial part of a professional racing driver's preparation for a competition.

The science behind these sophisticated modern-day race simulators lies within the human vestibular system, which comprises the small canals and bones in the inner ear. The utricle and saccule organs in the vestibular system help humans detect linear acceleration in three directions: vertical (for example, gravity), lateral (sway), and longitudinal (surges forward or backwards). In addition, three fluid-filled semi-circular canals are oriented in three planes to sense yaw, pitch and roll. As a person's body is moved about, tiny hair cells in the vestibule and semi-circular canals stimulate the vestibular nerve, helping the brain to interpret nerve impulses resulting from these six primary movements.

This is where the genius of new driving simulators come in: the movements of the simulator are designed to arouse a driver's vestibular nerves, creating a driving experience that's more true-to-life. As well as a real and working dashboard, the simulator is fitted with pedals that are hydraulically weighted the same as the car they're testing, and it's the same for the power steering 'feel' too. As for the graphics, they are displayed on a huge eight-metre (26-foot) screen and have a projection and resolution rate five times faster than that of a multiplex cinema, offering razor-sharp and, crucially, time-accurate images of the circuit that is being tested.

This all means simulators are a great way to get much needed practice on a circuit ahead of a race – particularly if it's a track that the driver has never visited before – and all done in familiar surroundings despite never actually sitting in a car. The accuracy of the facility means that time spent in the simulator is very nearly as good as doing the time in the cockpit itself, ensuring that the driver can enter a race buoyed by as much experience behind the wheel as possible.

Pedals
These feature vehicle-grade hydraulics and haptic actuators for accurate response and feel.

The lifestyle of a pro racing driver

You may think there's little else to the job of a professional racing driver than simply pulling up to the starting line and completing numerous laps of a circuit, but as Porsche's World Endurance Championship driver Nick Tandy tells us, you have to be 'race fit' to be able to pilot a modern race car.

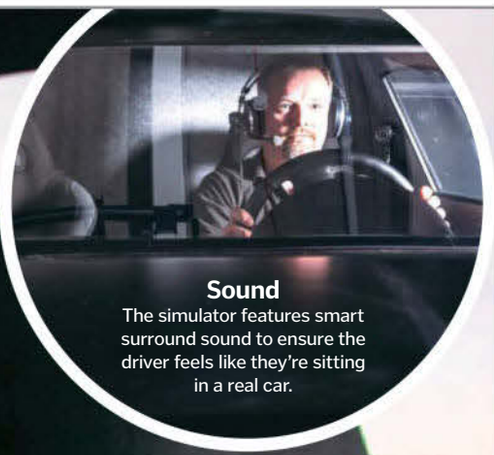
With cars even more powerful and capable of pulling high g-forces through every twist and turn of a race, the driver needs to be mentally and physically fit enough to handle these constraints on the body, particularly in an endurance race such as the Le Mans 24 Hours.

As such, pro drivers have intense fitness regimes and strict diet plans, with performance training to help improve reaction times and their acclimatisation to extreme heat. It doesn't end there, either: tactics are an important part of professional racing and drivers work hard to be attuned to the best setups of their car and driving style in all conditions, during every stage of a race.

Drivers need to be physically fit to withstand intense forces on the track

Inside the race simulator

Here's how a modern-day Delta race simulator provides a driving experience close to the real thing



Sound
The simulator features smart surround sound to ensure the driver feels like they're sitting in a real car.

Screen
The eight-metre (26-foot) surrounding screen displays the projection, which has a frame rate five times faster than a cinema screen.

Steering wheel
This is simulated to be weighted the same as the car in question, adding to the realism of the experience.

Cameras
Cameras and bio-sensors help a driver study their technique and timing of inputs for assessment.

Motion control system
This is built with the human vestibular system in mind. All movements made from this are designed to stimulate the driver's vestibular nerves.

Computer
This hardware records up to 300 channels of data from each race, for a driver to technically assess at a later date.

WHEN WORLDS COLLIDE

The Solar System may seem calm now, but long ago it was a chaotic and violent place...

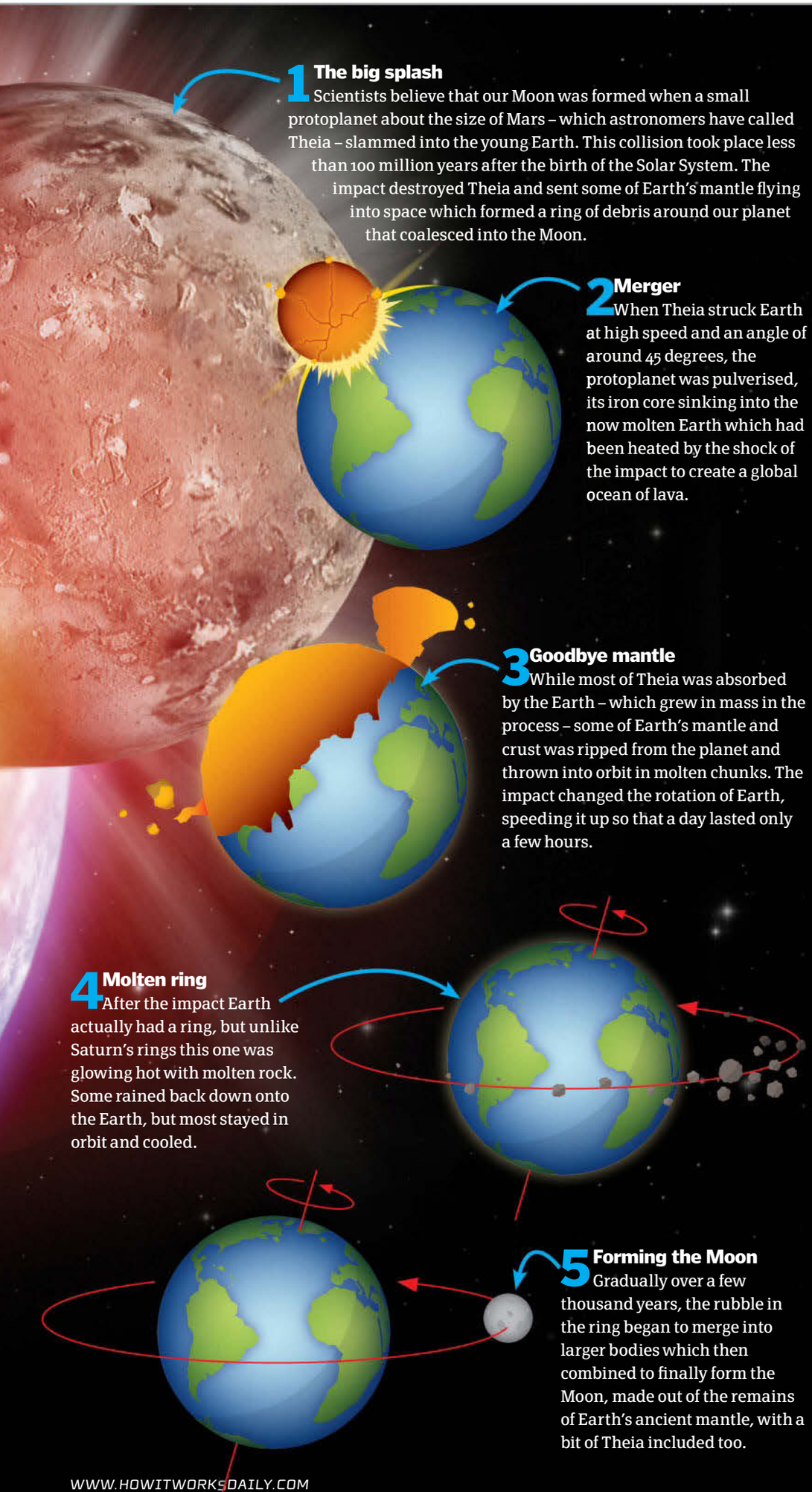
The planets in our Solar System currently orbit the Sun in stable orbits, always far enough away from the other planets to avoid a collision. This isn't always the case, though. Planets can and do collide, usually either when they are very young or very old.

Planets are made through collisions: young stars are surrounded by discs of gas and dust particles that collide and stick together, forming progressively larger chunks. A young planetary system can have dozens of 'protoplanets' flying around on unstable orbits. These crash and smash into each other, the debris from the collisions coalescing into larger and larger bodies. Earth is probably the result of many violent collisions, the last of which formed the Moon. Scientists using NASA's Spitzer Space Telescope have witnessed the dusty debris clouds that are the aftermath of such a collision around the star HD 172555, where two planets crashed at 36,000 kilometres (22,400 miles) per hour.

Some of the planets grow so large that they begin to siphon hydrogen away from the gaseous dust disc around their young parent star. Their accelerated growth soon sees them become gas giant planets, like Jupiter. However, as they steal gas from the disc around them, these planets lose angular momentum and begin to migrate inwards towards their star, steamrolling anything in their way. Smaller planets that are in the gas giant's path can be flung in all directions: some will collide with each other, or with their star, or be thrown out of their planetary system altogether.

Now, fast-forward billions of years to the death of these stars. Most will end their lives by becoming red giants, before casting off their outer layers in a planetary nebula, leaving behind a white dwarf. As the star swells into a red giant, it swallows the innermost planets, while those planets outside its grasp see their orbits widen due to the giant's lower mass. This can cause planets, comets and asteroids to collide. We see evidence for this in the form of the debris from these collisions contaminating the surface of the white dwarf.

Beyond the scale of solar systems, some truly cosmic collisions take place between entire galaxies. The Andromeda galaxy is currently heading straight for our Milky Way, due to collide in about four billion years from now. It might sound like the plot of a science fiction blockbuster, but mergers such as these are common in the universe and key to galaxy evolution.



1 The big splash
Scientists believe that our Moon was formed when a small protoplanet about the size of Mars – which astronomers have called Theia – slammed into the young Earth. This collision took place less than 100 million years after the birth of the Solar System. The impact destroyed Theia and sent some of Earth's mantle flying into space which formed a ring of debris around our planet that coalesced into the Moon.

2 Merger
When Theia struck Earth at high speed and an angle of around 45 degrees, the protoplanet was pulverised, its iron core sinking into the now molten Earth which had been heated by the shock of the impact to create a global ocean of lava.

3 Goodbye mantle
While most of Theia was absorbed by the Earth – which grew in mass in the process – some of Earth's mantle and crust was ripped from the planet and thrown into orbit in molten chunks. The impact changed the rotation of Earth, speeding it up so that a day lasted only a few hours.

4 Molten ring
After the impact Earth actually had a ring, but unlike Saturn's rings this one was glowing hot with molten rock. Some rained back down onto the Earth, but most stayed in orbit and cooled.

5 Forming the Moon
Gradually over a few thousand years, the rubble in the ring began to merge into larger bodies which then combined to finally form the Moon, made out of the remains of Earth's ancient mantle, with a bit of Theia included too.

"Planets can and do collide, usually either when they are very young or very old"

The giant impact hypothesis

The main evidence for the theory that the Moon was formed by a giant impact comes from lunar rocks returned to Earth during the Apollo missions. These rocks contain ratios of oxygen isotopes (atoms of a given element that have a different number of neutrons) that are almost exactly the same as those found in Earth's mantle, indicating that the Moon is made from material that came from our planet's mantle. Material in the Moon rocks was also found to have once been molten, long ago, and an impact would have provided the necessary energy to efficiently melt rock.

Although the impact theory is now widely accepted, a number of puzzling problems remain. For example, some believe there should be more evidence of debris material from Theia found in the Moon rocks. Also, the rocks contain so-called volatile elements (materials that evaporate easily in relatively low temperatures) such as water, which were embedded in the rocks when they formed, yet the heat of an impact should have evaporated them. However, these puzzles remain as details to be ironed out, rather than serious threats to the impact theory.

A 77g (2.7oz), golf-ball-sized piece of Moon rock that was collected by astronaut Dave Scott during the Apollo 15 mission

© Thinkstock; University of Arizona/Tom Story

This is an artist's impression of the asteroid collision around the star NGC 2547-ID8, which released a huge cloud of dust

ASTEROID COLLISIONS

Space rock smash-ups happen once per year in the asteroid belt

Forget the asteroid chase scene in *The Empire Strikes Back* – the asteroid belt is really quite empty – you could be standing on one asteroid and not be able to see another! Even so, that doesn't stop them from bumping into each other and when they do, it can be dramatic.

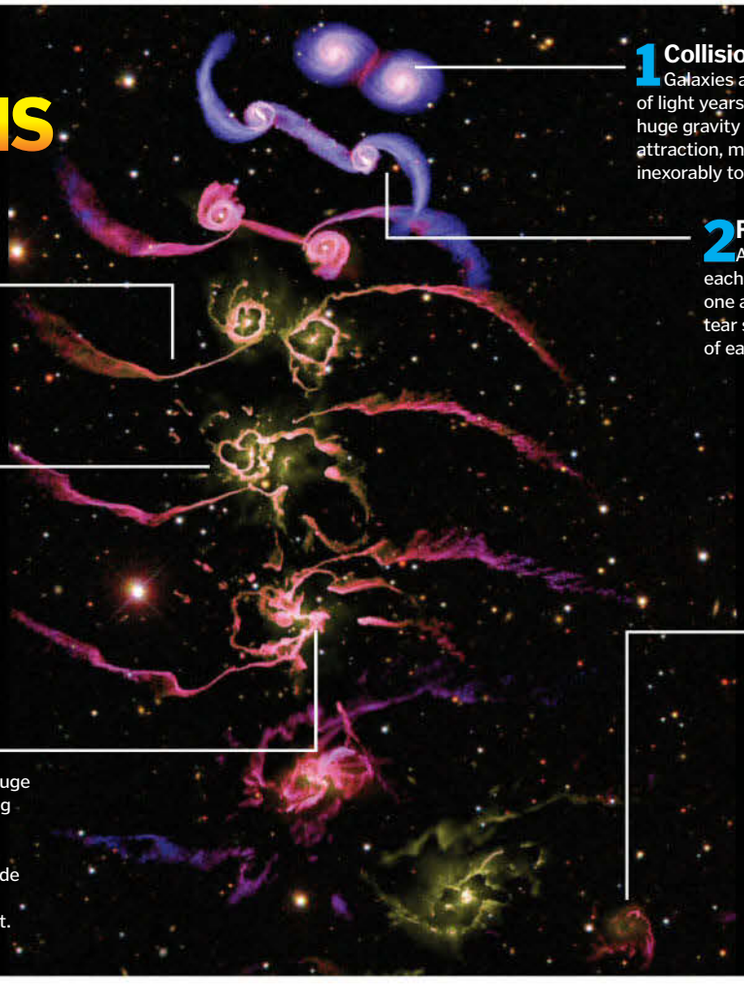
In 2010 the Hubble Space Telescope spotted something mysterious in the asteroid belt: a strange, X-shaped object with a long tail like a comet. The tail was asteroid dust, believed to be released when a 122-metre (400-foot) wide asteroid collided with a smaller asteroid, about 4.6 metres (15 feet) across, which struck it at a velocity of 17,700 kilometres (11,000 miles) per hour. Astronomers suspect impacts like this could happen between minor asteroidal bodies in the asteroid belt about once per year, on average.

Some asteroids come in groups or families. The families are believed to be chunks of the largest member of the family, smashed off in an impact. For example, Vesta – one of the largest asteroids in the Solar System – has a family of smaller asteroids, while a rare type of meteorite found on Earth, called HED (howardite-eucrite-diogenite) meteorites, are believed to come from this family as well. Sometimes, collisions can send asteroids larger than these small meteorites our way too, and when that happens they can endanger life on Earth.

Asteroid collisions happen around other stars, too. In 2012 a star called NGC 2547-ID8 suddenly found itself having much more dust around it than it used to have, released by a giant asteroid impact. Spitzer saw the infrared emission from this dust, which contains sand-sized grains that are grinding themselves down even smaller.

GALAXY COLLISIONS

What happens when these swirling systems of stars meet?



1 Collision course
Galaxies are usually millions of light years apart, but their huge gravity can cause an attraction, making them move inexorably towards one another.

2 First contact
At first, the momentum of each galaxy may take them past one another, but their gravity will tear streams of stars and gas out of each other, called tidal tails.

3 Tidal tails
These can stretch hundreds of thousands of light years and the gas within them can form many new stars, far away from their home galaxy.

4 Caught by gravity
Although the two galaxies pass each other, their mutual gravity prevents them from escaping and pulls them back. This could happen several times, yo-yoing to and fro, until they are moving slowly enough to begin merging.

5 Stars
During the merger, huge gas clouds collide, causing them to form new stars. However, amid a galaxy collision, stars rarely collide because the distances between them are so vast.

6 Elliptical galaxy
If two spiral galaxies collide, their characteristic arms become distorted. The galaxies merge into a combined blob-shaped galaxy called an elliptical, and their supermassive black holes also merge.

‘MILKOMEDA’

Our Milky Way galaxy is doomed, stuck on a collision course with another galaxy

Like lovers in a last embrace, our Milky Way and the Andromeda galaxy are caught in a mutual pull of gravity and are hurtling towards each other at 112 kilometres (69 miles) per second. In about four billion years’ time they will come into contact with each other, and we can expect to see the same interactions between our galaxy and Andromeda as we have witnessed in galaxy collisions elsewhere in the universe. It is unlikely that individual stars will collide (so if the Sun is still around, it will be safe) but the galaxy’s spiral arms will be twisted and pulled apart, and stars and gas will be flung out in tidal streams. The black hole at the heart of our galaxy will then merge with the black hole inside Andromeda, possibly becoming active for a time as huge amounts of gas are pushed down its throat by the gravitational forces of the collision. The end result will be a giant elliptical galaxy that some astronomers have nicknamed ‘Milkomeda’. Some also suspect that another nearby spiral galaxy, the Triangulum galaxy, will also play a part in the merger as it comes close.

Menage à trois
The Triangulum galaxy, lurking about three million light years away, will also eventually merge with the new elliptical ‘Milkomeda’.

Collision
In four billion years’ time the Andromeda galaxy will merge with the Milky Way and form a giant elliptical galaxy.

The Andromeda galaxy
Currently 2.5 million light years away, the Andromeda galaxy is hurtling towards us at 400,000km/h (250,000mph).

Survival of the Sun
During such collisions it is rare for stars to collide, but the Sun may well be ejected to the outskirts of the new elliptical.

What will we see? Earth’s night sky will change dramatically over the next four billion years

Present day
We can see the Milky Way and the Andromeda galaxy spanning three degrees in the sky. However, Andromeda has a blueshift meaning it’s moving towards us.

The encounter begins
As the Andromeda galaxy gets nearer it will grow larger in our sky. Its invisible gravitational force will begin to distort the shape of the Milky Way.

Collision!
As the spiral arms of the two galaxies plough into each other, their structures are completely disrupted. From Earth we will see the Milky Way become misshapen and tangled.

Starburst
During the merger huge gas clouds collide, creating the conditions for a burst of star formation. In the night sky we will see more nebulae and bright star clusters light up.

Black holes
The black holes in each galaxy edge their way towards each other. From Earth, we will see two galactic cores, getting closer until they merge.

The end result
Eventually the star formation ends, the black holes merge, the spiral arms are destroyed, and the two galaxies form a blob of stars called an elliptical galaxy.

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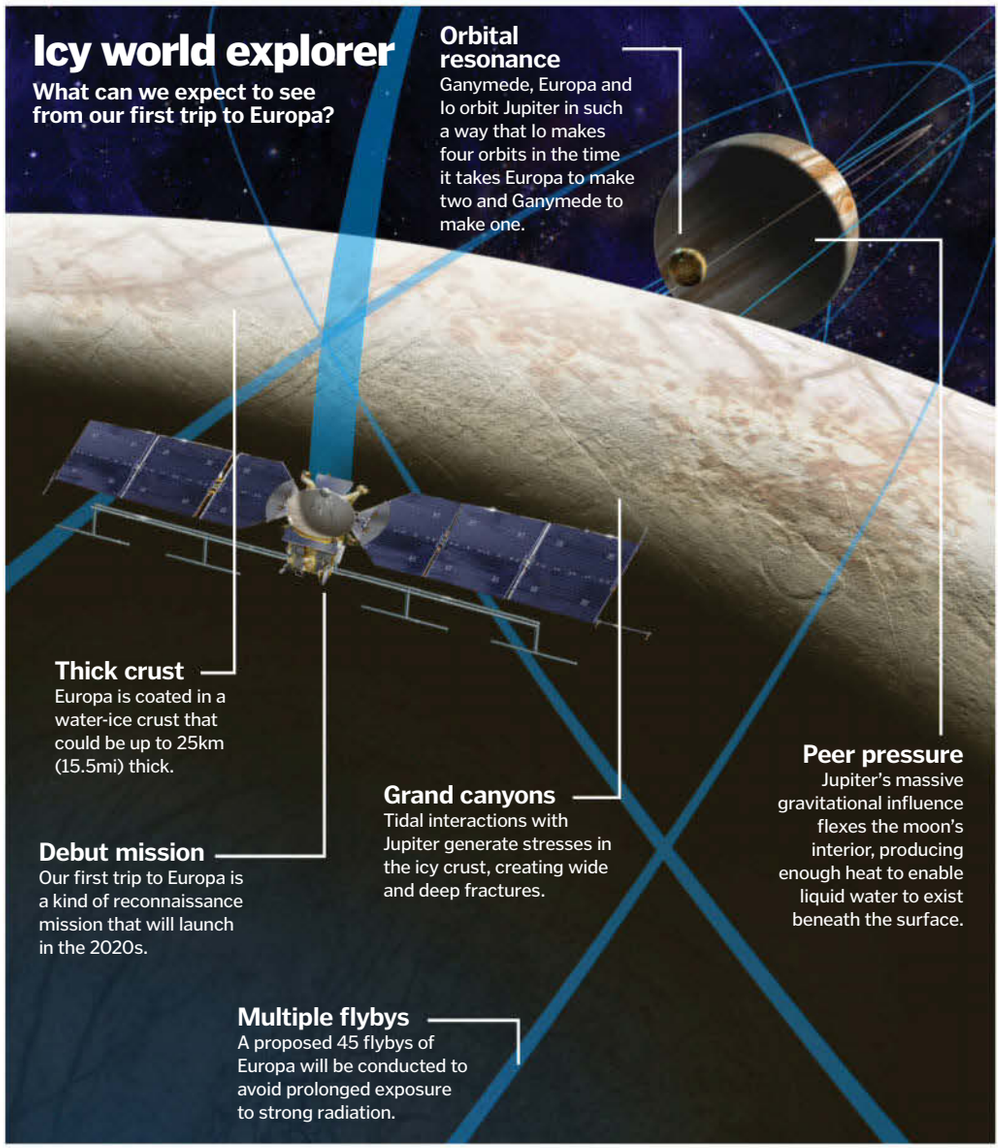
How NASA's Europa mission works

Jupiter's icy moon is next on NASA's hit list: here's why and how we're going to explore it

In May, following federal allocation of funds for the coming year, NASA announced the selection of a series of scientific instruments it would use to investigate potential life on an icy moon, along with a 2020s mission to Europa. This is one of Jupiter's largest natural satellites and, courtesy of its role in various science fiction novels and films, perhaps one of the most famous objects in the Solar System.

Europa isn't just the next logical stepping-stone from Mars into the outer Solar System though: it's a frozen world at the surface with an icy crust, and there's strong evidence for a large sub-surface water ocean beneath it. In many ways it's a remarkably similar place to the lakes found beneath the kilometres-thick ice of Antarctica, where several space agencies (including NASA) have conducted experiments for years, so this isn't a wholly alien environment to us. Furthermore, life has been found in sub-surface Antarctic lakes that have been devoid of any sunlight for tens of thousands, or even millions of years. This means Europa has the potential to be habitable, even if life never occurred on it.

The current proposal is for a hardy probe that can withstand the intense radiation belts around Jupiter to make the 600 million-kilometre (373 million-mile) journey to the gas giant. Here it will orbit Jupiter and perform 45 flybys of Europa – swooping as low as 25 kilometres (16 miles) above the surface – scanning the moon to determine the thickness of the ice and where its subsurface lakes might be found. If the reconnaissance mission is a success, scientists could follow up with a landing mission and a probe to send beneath the ice crust to search for life in the frigid depths.



What is the squid rover?

NASA's calling it the 'Soft-Robotic Rover with Electrodynamic Power Scavenging' – but the concept of this aquatic rover was inspired by the squid and so the catchier 'squid rover' has stuck. It certainly resembles this terrestrial mollusc.

The squid rover will plummet into the dark and cold depths of Europa's sub-surface oceans, where no nuclear or solar-powered rover can hope to survive. It will 'scavenge' its power from its environment, using two tentacle-like appendages to electrolyse the water around it. It will then produce hydrogen and oxygen gas to provide the fuel for its propulsion systems, as well as generating electricity for both communications and alien life-seeking scientific instruments.

This technology is very much in the concept phase, but NASA is taking its development seriously. If successful, the squid rover would solve the problem of powering a craft so far away from the Sun. On top of that, it would be an effective propulsion system through the sub-surface oceans, which are suspected to lie beneath the icy surface of many outer Solar System worlds.

This soft-bodied rover will search for habitable environments in sub-surface oceans on other worlds

© NASA

How are exoplanets found?

Discover how we'll be spotting alien worlds now and in the future

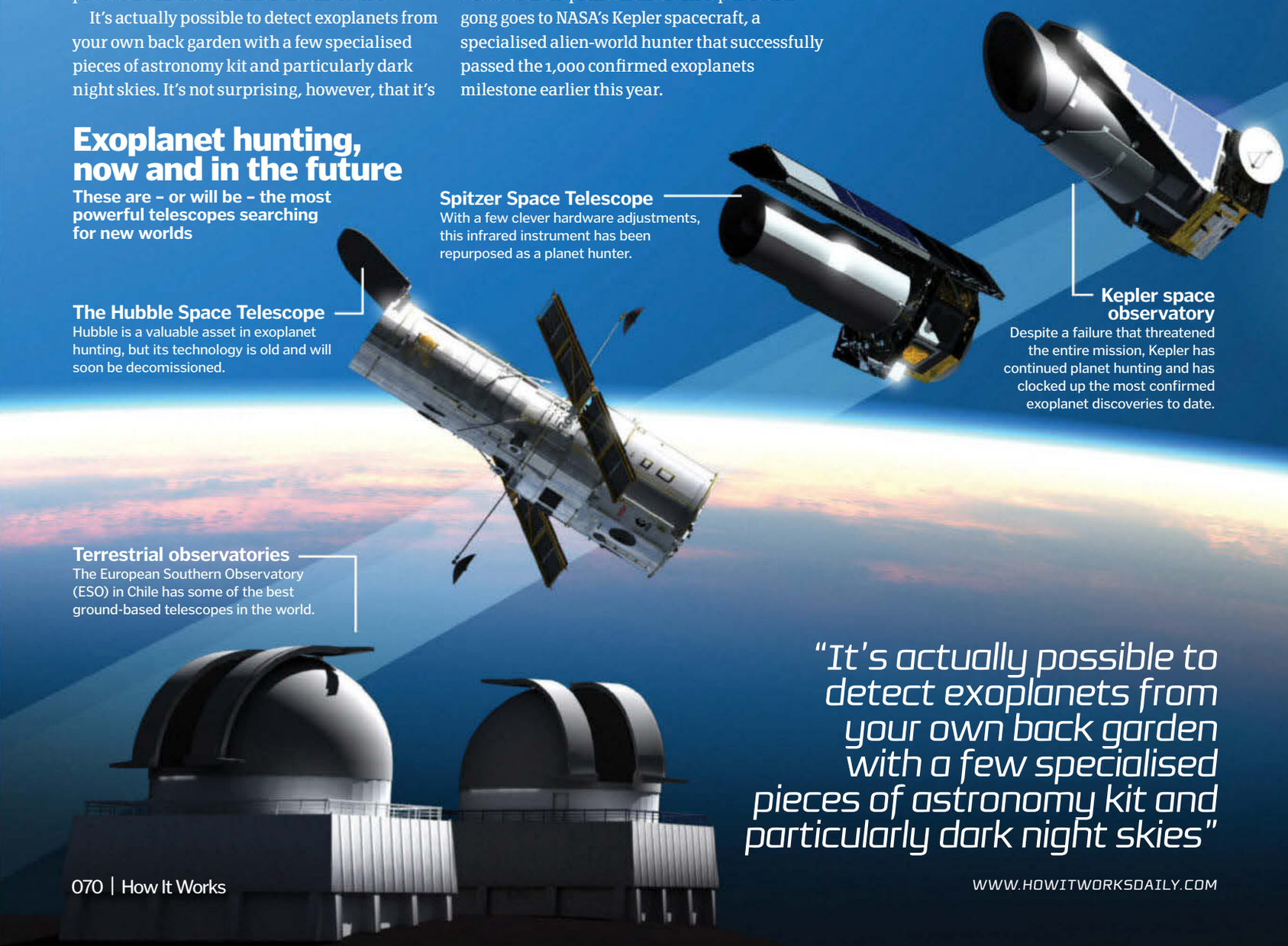
Scientists had suspected that exoplanets – planets beyond our Solar System – had existed for several hundred years, long before the first confirmed detection was made. Over the years some claimed to have discovered an exoplanet, but it wasn't until 1992 that the detection of a planetary-mass object orbiting a type of star – known as a millisecond pulsar – was confirmed. That observation took the power of the giant Arecibo radio telescope in Puerto Rico and some out-of-the-box thinking to detect – techniques that are now standard procedure in the search for distant worlds.

It's actually possible to detect exoplanets from your own back garden with a few specialised pieces of astronomy kit and particularly dark night skies. It's not surprising, however, that it's the big ground-based and space observatories, run by various government agencies and organisations around the world, that have made nearly 2,000 confirmed detections to date. Most of these discoveries have been made by space telescopes at their vantage point 1.5 million kilometres (932,057 miles) away from Earth's obscuring atmosphere. Hubble, which had been in orbit for two years by the time the first exoplanet was confirmed, has discovered a handful of these and has contributed to the discovery of many others, but it isn't the most successful exoplanet hunter. That particular gong goes to NASA's Kepler spacecraft, a specialised alien-world hunter that successfully passed the 1,000 confirmed exoplanets milestone earlier this year.

Of course, the total number of exoplanets we've discovered so far is a drop in the ocean: the Gaia telescope was launched in late 2013 to map a billion stars, or about one per cent of our own galaxy, and will help in the search for new worlds by finding the host stars that they orbit. However, given that there's an estimated average of one planet for every star in the Milky Way, we've still got a long way to go.

Exoplanet hunting, now and in the future

These are – or will be – the most powerful telescopes searching for new worlds



Spitzer Space Telescope
With a few clever hardware adjustments, this infrared instrument has been repurposed as a planet hunter.

The Hubble Space Telescope
Hubble is a valuable asset in exoplanet hunting, but its technology is old and will soon be decomissioned.

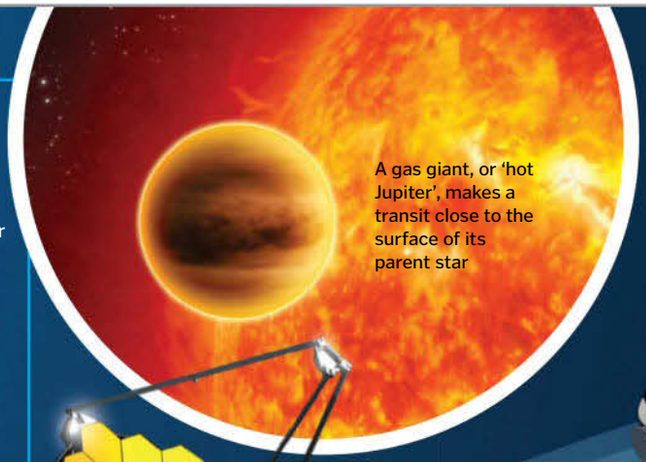
Kepler space observatory
Despite a failure that threatened the entire mission, Kepler has continued planet hunting and has clocked up the most confirmed exoplanet discoveries to date.

Terrestrial observatories
The European Southern Observatory (ESO) in Chile has some of the best ground-based telescopes in the world.

"It's actually possible to detect exoplanets from your own back garden with a few specialised pieces of astronomy kit and particularly dark night skies"

Detection methods

Building a top-notch observatory with current technology is half the battle: it's not just a matter of pointing your telescope and hoping to see something. This is because planets don't emit any light of their own, they can be thousands of light years from us and they're usually found orbiting stars, which means they're lost in the bright starlight. Astronomers have developed several techniques to detect exoplanets indirectly, in other words, by making observations that infer the existence of a planet. By far the most successful is the transit method, which measures the miniscule decrease in the levels of light from a star when an orbiting planet passes in front of it. It has its limitations, of course, but this method accounts for over two thirds of confirmed exoplanet detections.



A gas giant, or 'hot Jupiter', makes a transit close to the surface of its parent star

Wide-Field Infrared Survey Telescope (WFIRST)
Its primary science will be to answer questions about dark energy, but it will also search for solar systems like our own.

James Webb Space Telescope (JWST)
This hotly anticipated observatory will launch in 2018 and sees in visible wavelength to infrared in unprecedented resolution.

Transiting Exoplanet Survey Satellite (TESS)
Due to launch in 2017, TESS will survey the nearest and brightest stars to us, providing targets for further observation.

Advanced Technology Large-Aperture Space Telescope (ATLAST)
A potential successor to Hubble and the JWST, the ATLAST mission would search for biosignatures (signs of life) on other worlds in our galaxy.

Earth's bigger, older cousin

NASA's Kepler mission has recently discovered a planet that closely resembles Earth and orbits within a 'habitable zone' – an area around a star where it's warm enough for water to be liquid. It may therefore offer just the right conditions for supporting life. Named Kepler-452b, the planet is 60 per cent larger in diameter than Earth and is considered a super-Earth-size planet. Its mass and composition have not yet been determined, but previous research suggests that planets the size of Kepler-452b have a good chance of being rocky. While it is larger than Earth, its 385-day orbit is only five per cent longer because the planet is five per cent farther from its parent star, Kepler-452, than Earth is from the Sun. Kepler-452 is six billion years old, 1.5 billion years older than our Sun, but has the same temperature, is 20 per cent brighter and has a diameter ten per cent larger. The Kepler-452 system is 1,400 light years away in the constellation Cygnus.

Kepler-452b is the most recent planet discovered by NASA's Kepler mission that closely resembles Earth

© ESA; NASA

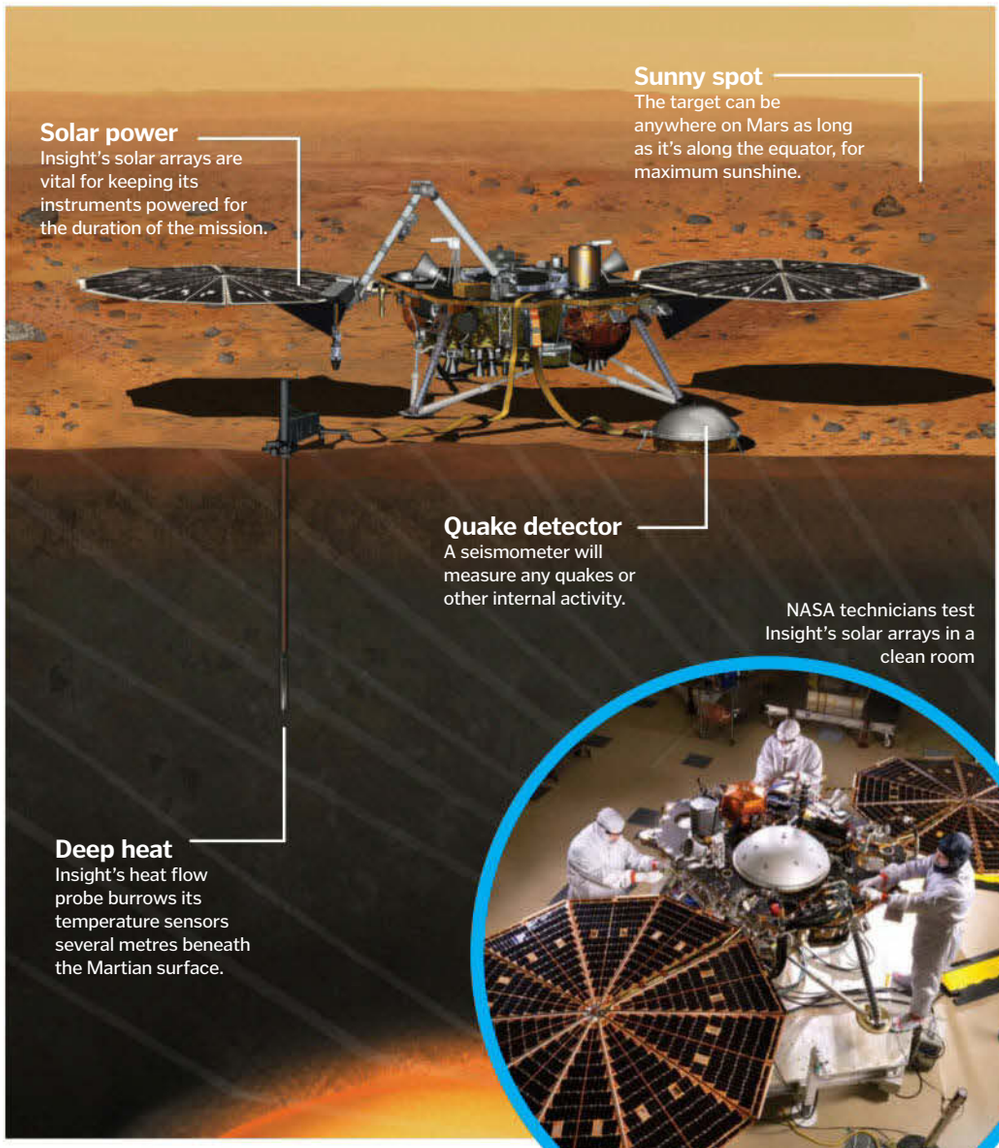
What is the new Mars lander?

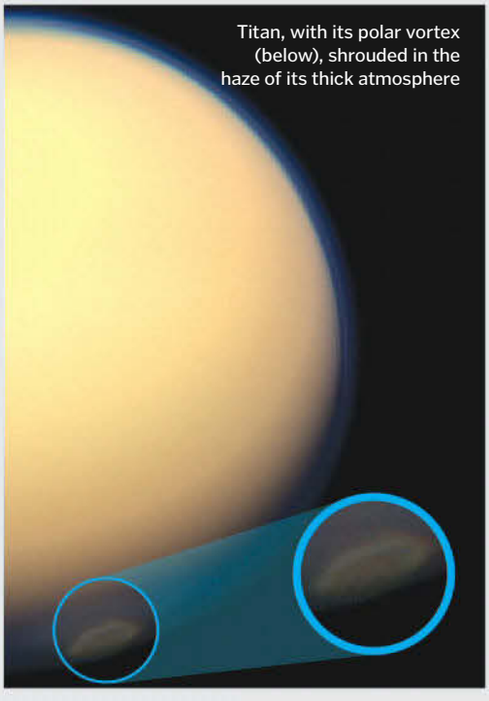
NASA's next mission will offer clues about the formation of the Solar System

We might have sent over a dozen rovers, landers and orbiters to Mars, but that doesn't mean we are done sending probes to the Red Planet – we still have a lot to discover.

NASA's InSight (Interior Exploration using Seismic Investigations) lander is planned to launch in March 2016 and will touch down on the Martian surface just six months later. As the acronym suggests, its two-year mission will involve peering deep beneath the Martian crust at a landing site near the equator to study Mars' internal processes and structure, as well as any tectonic activity and meteorite impacts.

This is much more than figuring out what Mars is made of or even the history of this one planet. Geologically, Mars is practically inert compared to a planet like Earth, as it has no plate tectonics, and so there is a much more complete history of how it has evolved over the last few billion years. Therefore by investigating Mars's interior, scientists will be able to gain a much better understanding of how all of the terrestrial planets formed.




Titan, with its polar vortex (below), shrouded in the haze of its thick atmosphere

Is Titan Earth's toxic twin?

It's bitterly cold and shrouded in a choking natural 'smog', but Titan is more like Earth than you'd think

Venus is often referred to as 'Earth's evil twin' because, despite having similar characteristics and evolutionary starting line, it went on to become the inhospitable world that it is today. However, a team of scientists from University College London (UCL) have dubbed the giant moon Titan 'Earth's toxic twin' for a few slightly different reasons.

Saturn's biggest natural satellite is the only other place in the Solar System where it rains, has rivers and surface oceans – of liquid hydrocarbons (like ethane and methane), rather than water. These were recorded during descent of the Huygens probe, the only spacecraft to have successfully landed on any celestial body in the outer Solar System, in 2005.

The team at UCL has found that in Titan's dense, hazy atmosphere there is also a polar wind that works in a similar way to that of Earth's, driving around seven tons of nitrogen and methane gases out of the atmosphere and into space every day. It's thought that both Mars and Venus could feature similar polar winds, and it also begs the question: if so many worlds are similar to Earth in this Solar System alone, how long can it be before we find another planet capable of supporting life?

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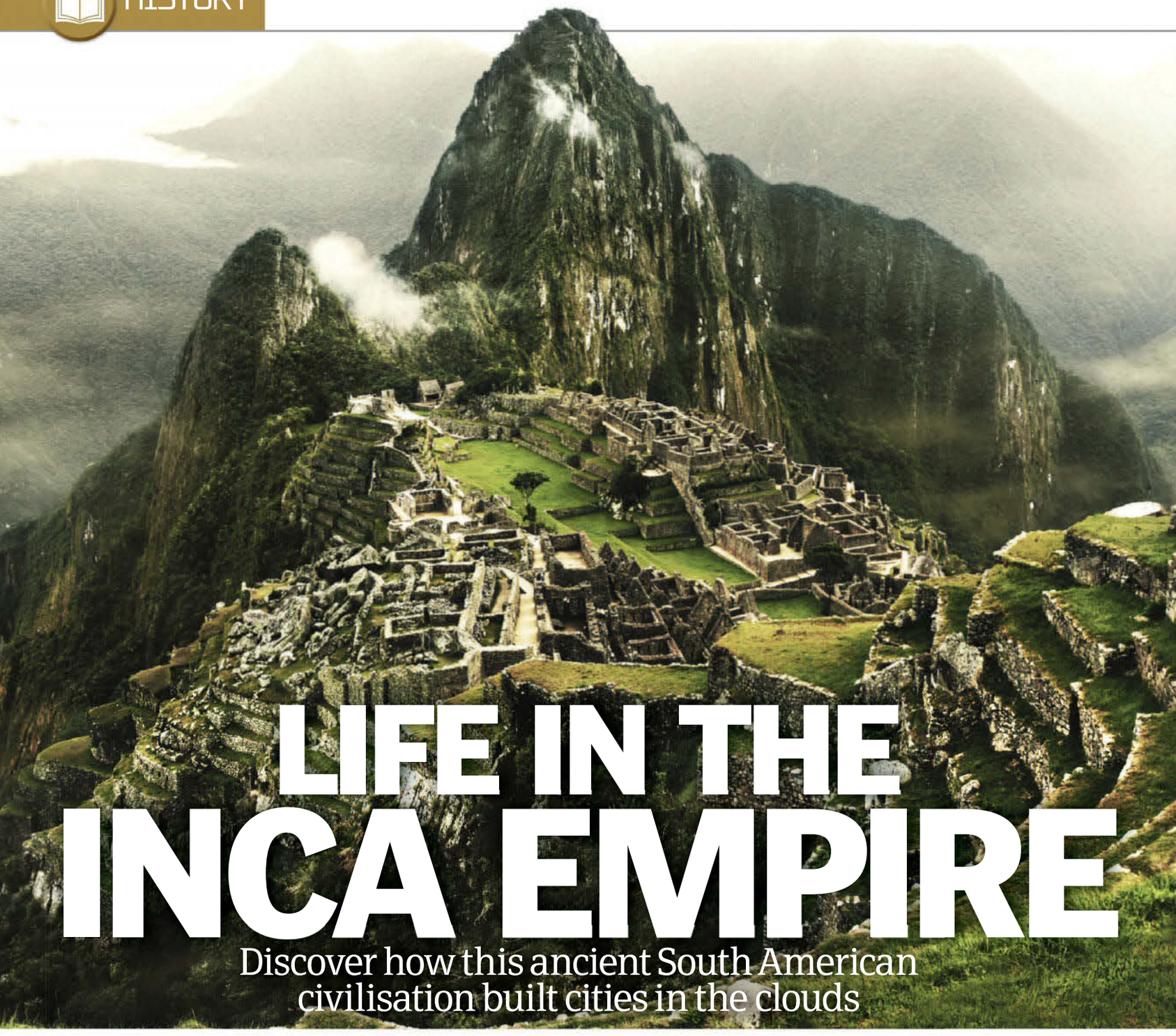


LIFE IN THE INCA EMPIRE

Discover how this ancient South American civilisation built cities in the clouds

In less than a century the Incas built an empire that stretched over 3,862 kilometres (2,400 miles) along the west coast of South America, making it the largest nation in the world at that time. Not only did they do this without the wheel, horses, or a formal written language, they also had to navigate deserts, rainforests and the highest mountain range on the continent, the Andes.

The civilisation's ruler was known as the Sapa Inca, who led from the capital of Cuzco in present-day Peru. King Pachacuti was the first leader to expand beyond this region in the early 15th century, sending his army to conquer new territories. Inca warriors were fearless, well-disciplined and skilled at using a number of weapons, but it was the organisation of the Inca government that really made their conquests a success.

The Incas called their empire Tawantinsuyu ("the four parts together"), as they divided it into the northeast, southeast, northwest and southwest regions. Each region had its own governor and group of local administrators to oversee the settlements and report back to the Sapa Inca. When new areas were conquered, Inca officials were sent to facilitate the spread of their customs, language and general way of life, resulting in the iconic settlements we see today.

However, in 1532, the Inca Empire collapsed just as quickly as it had started. Spanish conquistadors, led by Francisco Pizarro, took advantage of the rebellions and epidemics of European diseases that were rife in the region at the time, and took the land for their own.

Examples of the Inca way of life still live on, as many villagers dwelling in the Andes speak the Quechua language and farm the land as the Incas did 500 years ago. Some Inca cities also managed to escape destruction by the Spanish. One of the best-preserved sites is Machu Picchu, located 2,430 metres (7,972 feet) above sea level. There are several theories about the site's purpose, but one popular idea is that Machu Picchu was a royal estate for the Sapa Inca. This ancient city in the clouds is now a UNESCO World Heritage Site that gives tourists a glimpse into the past.

Anatomy of an Inca warrior

The fierce soldiers that helped expand the Inca Empire

Feathers
Helmets were adorned with brightly coloured feathers. The number of feathers distinguished military ranking.

Helmet
High-ranking warriors wore helmets made of copper or bronze, but regular fighters had wooden headgear.

Jewellery
High-ranking warriors wore plates of gold, silver or bronze on their chests, and gold or silver earplugs to stretch their lobes.

Shield
Shields came in a variety of shapes, made from wood covered in leather or hide, and were mainly used by high-ranking soldiers.

Tunic
Made from thick, padded cotton with plates of stone or metal on the back and front, the tunic provided protection against wooden and stone weapons.

Weapon
The Incas used a variety of weapons depending on their position in the battle, including spears, slingshots, bows, clubs and axes.

Fringes
Fringes of wool were tied around the biceps, ankles and below the knees, which was believed to strengthen the limbs.

Colours
Tunics were designed with specific colours and insignia corresponding to the region of the army.

Sandals
Footwear was crafted from untanned llama hide or braided fibre, helping them walk for miles into battle.

The Incas made clothing using backstrap looms. Wool or cotton was wrapped around two pieces of wood, and then more material was weaved through horizontally

Messenger service

As their empire expanded, the Incas built a vast network of roads and bridges to connect their settlements. However, as they had no wheeled vehicles or horses, journeys were made on foot using llamas or alpacas to carry any heavy supplies. One important use for these roads was the delivery of verbal messages, as the Incas had no written language. Runners were located at stations along each route and would pass on their message when they reached the next station, a bit like a relay race. They would mostly deliver news of invasions, uprisings, or the Sapa Inca's death, but occasionally recorded information that needed to be sent. This was done using a quipu, a rope with a series of strings suspended from it. The colour of each string indicated what was being counted, such as how many soldiers were available for war, and the number of knots denoted the amount.

The quipu was used to record everything from the length of a ruler's reign to how many crops a settlement produced

Manual labour

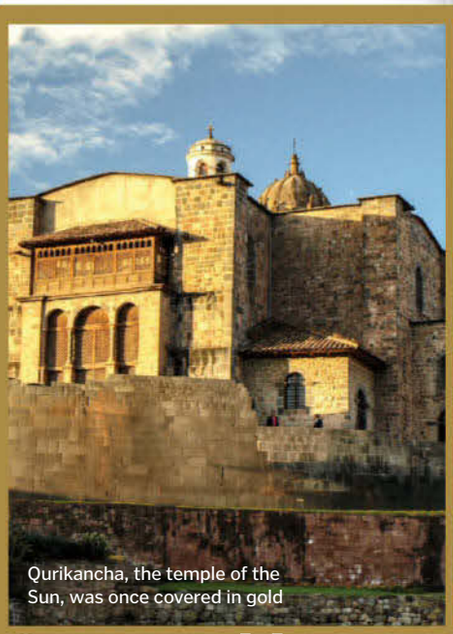
The families at the bottom of the Inca hierarchy were mainly farmers. As there was no currency, land was allocated to each family by the state and in return they would pay tax in the form of food and textiles. These families could only keep some of the food they produced for their own use, as the rest was divided between offers for the gods and the state. Every adult was also required to spend part of each year working for the state, helping to build houses and roads or by joining the army. The Incas also used their building skills to find clever ways to farm uneven mountain slopes. One solution was to cut terraces into the hillside and build walls to keep the soil in place.

Terracing helped to extend the farmland and prevented soil from being washed away

Inca architecture

How the Incas built impressive structures and simple homes

The Incas were excellent stonemasons, constructing buildings that were uniform in design, incredibly stable and pleasing to the eye. The clean lines and trapezoidal windows and doorways in their structures soon became recognisable as their settlements spread west across South America. Grand palaces and humble homes were built in much the same way, and could only be differentiated by their size and the quality of the stone finish. Some more ambitious designs also featured curved walls and gold sheeting, but most buildings were much simpler. Homes were typically built in a kancha, an enclosure of several single-room structures built around a courtyard and enclosed by a wall.



Qurikancha, the temple of the Sun, was once covered in gold

Sun worship

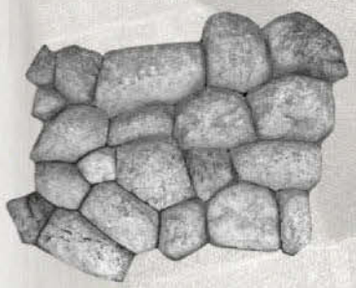
The Incas worshipped several nature gods, including a Moon goddess and a god of thunder, as they were believed to control the natural world and prevent disasters such as floods and droughts. However, one of their most important gods was Inti, the Sun god and giver of heat and light. Inca rulers were regarded as Inti's representative on Earth and the Incas considered themselves the 'children of the Sun'. Their religious ceremonies took place according to the movements of the Sun, with offerings of food, drink, and animal and human sacrifices made to Inti. Most buildings, doors and windows were constructed to align with the sunrise and other astronomical events, and temples were also devoted to the Sun god. One of the most sacred buildings, the Qurikancha temple in the capital of Cuzco, was once covered in gold to reflect the Sun's light and represent its power.

Building materials

Inca houses were built from stone blocks shaped using harder stones and bronze tools. These blocks could weigh many tons and were moved using a system of ropes, logs, levers and ramps. It could take many months to build a single wall.

Grand structures

Stone blocks were cut so precisely that they interlocked perfectly, and no mortar was necessary to hold the walls together.



Simple dwellings

Smaller stones were set into place with mud, or dried mud bricks called adobe were used instead.

"Grand palaces and humble homes were built in much the same way"

Housing

Take a look inside a traditional Inca abode

Thatched roof
Wooden poles were tied together with rope and fixed to the walls with pegs. Then thatched grasses or reeds were placed on top.

Basic furniture
The Incas did not have beds or chairs; they would sit and sleep on mats on the floor.

Earthquake-proof
The sloping walls and interlocking bricks helped the buildings withstand the regular tremors experienced in the region.

Decoration
Deep recesses in the walls held statuettes of the religious figures that the Incas worshipped.

Single room
Most houses had one rectangular room and one entrance, but some had an upper floor accessible by ladders made from rope and wood.

Sloping walls
The exterior walls usually sloped inwards giving the building a trapezoid shape that was echoed in the windows and doors.

ON THE MAP

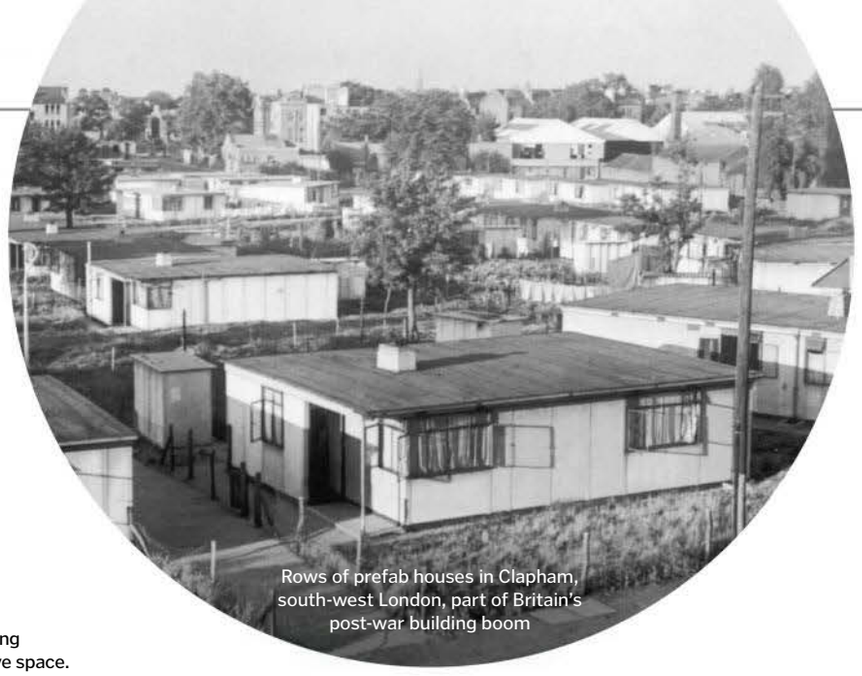
Growth of the Inca Empire

1. 1438-1471: King Pachacuti Inca Yupanqui launched the first conquests beyond the Cuzco region.
2. 1471-1493: Pachacuti's son Topa Inca Yupanqui pushed up the coast to defeat the Chimú Kingdom in what is now northern Peru.
3. 1493-c.1525: Huayna Capac, the son of Topa, expanded the Empire's reach southwards through Chile.
4. c.1525-1532: Huayna's son Huáscar made a final push into the northwest before the Spanish arrived.

© Corbis; Dreamstime; Sol90; Thinkstock

WWII prefabricated buildings

How this prefabulous plan solved the post-war housing crisis

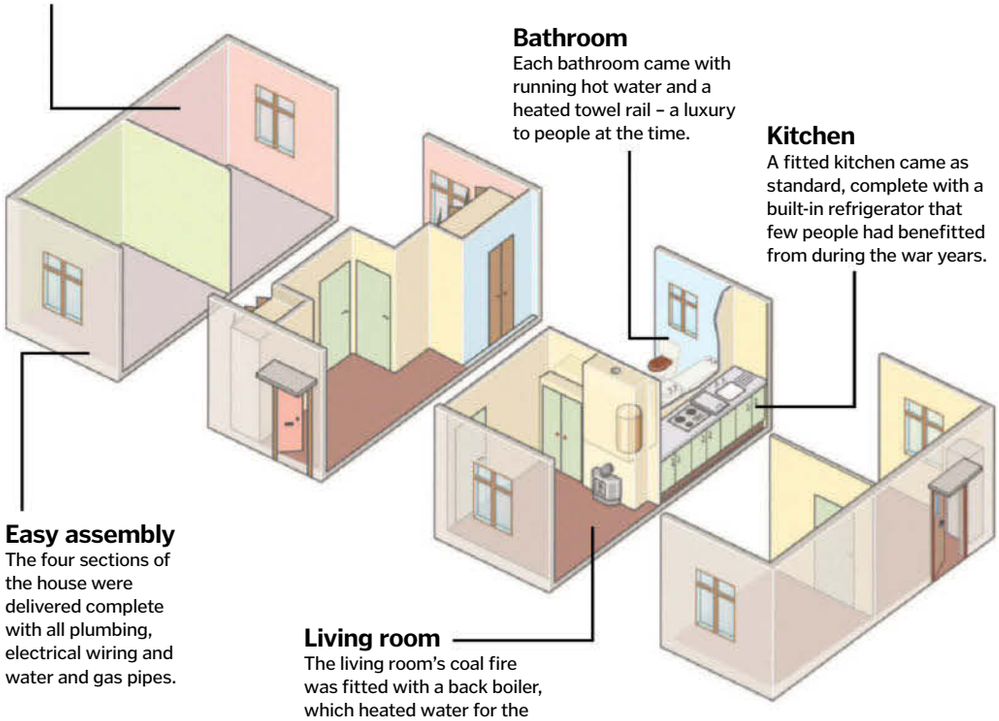


Rows of prefab houses in Clapham, south-west London, part of Britain's post-war building boom

As soon as war began in 1939 house building effectively stopped, with all efforts directed towards fighting the war. By the end of World War II, many thousands of Britons had been made homeless by German bombings during the Blitz and were living with friends or family. Some were even forced to squat in unused buildings and Underground stations.

To address the housing shortage, Winston Churchill, who was the Prime Minister at the time, decided he would make use of the vast array of munitions factories and turn them into housing factories instead. He proposed the large-scale production of prefabricated buildings, which could quickly provide houses as the country began to rebuild after the war.

One of the most popular prefab designs was the aluminium Type B2, which took only 12 minutes to manufacture as four separate sections. The pieces were then transported to their final destination on the back of a lorry, where they could be quickly assembled. By 1949 more than 156,000 prefabricated homes had been built. These homes had been designed to last for around ten years but many remained in use for much longer, with some still being occupied throughout the early 2000s.



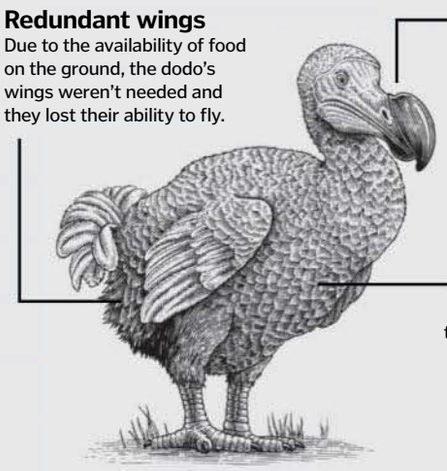
Why did the dodo become extinct?

From thriving to non-existent in less than 100 years

One of the most famous extinction cases in history, the dodo once inhabited the island of Mauritius in the Indian Ocean, where it thrived due to an abundance of food and a total lack of threat from predation. The bird was in many ways a victim of its own evolution, as over time it lost the ability to fly due to the abundance of food on the ground. The wings withered away while the body grew bigger and heavier.

When Dutch sailors arrived in Mauritius at the end of the 16th century, the dodo made for a quick and nutritious meal that could be hunted with ease. Without any natural predators, the bird was too trusting.

Eggs and chicks soon came under fire when the explorers began to bring foreign animals with them. Rats, dogs and cats raided their nests, while colonisation destroyed their habitat. This is likely to be the fastest extinction in history and underlines just how quickly human interaction can ruin the lives of a native species.



© Alamy

How sculptors worked

Learn the ancient methods of the Greeks who cast legends into stone

Ancient Greece was a civilisation full of drama, majesty and legend that is evident in the art they left behind. However, many of the statues that we know are actually copies of Roman origin – we owe the Romans a lot for their preservation of art that would otherwise have been lost forever!

Greek sculptors would begin their craft with a few blocks of stone – this was often marble or limestone that was readily available in Greece. The tools and techniques that the stonemasons used have changed very little over thousands of years and are similar to the ones worked with today. Marble was the most popular to use, but sculptors would pick their blocks for their workability rather than beauty.

These large statues of stone are incredibly heavy and so the sculptors would employ a few tricks to reduce weight and enhance stability. Statues would often have an extra support, such as tree trunk or column, to provide a solid foundation for the figure on the plinth than just its two feet. Masons would sometimes hollow-out the inside of a sculpture in order to keep weight at a minimum.

Once statues were finished, they would often be adorned with bronze accessories such as spears and jewellery. The eyes would be inlaid with glass or bone to bring them to life and some statues had bronze discs on the head, known as 'meniskoi' to prevent birds from defacing the figure.

Bronze sculpture

Bronze is an alloy made of roughly ninety per cent copper and ten per cent tin; copper was readily available around the Mediterranean and tin was imported. Early Greek sculptors used a method known as 'sphyrelaton' – meaning 'hammer-driven' – to create their masterpieces. Sculptors would hammer a sheet of the metal over a piece of wood carved into the desired shape, then fix the different pieces together.

As time moved on, lost-wax casting then became the most popular technique for bronze statuary. This involved various different ways of using wax and clay to create moulds, then heating so that the wax melted to leave a recess into which the molten bronze could be poured.

Bronze could also be re-used, melted down and turned into something new. This means that there are few Ancient Greek bronze sculptures left for us to find, and the ones that we do have are incredible pieces of history.

These 2,500 year old bronze statues were found in the sea near Riace, Italy in 1974

Making of a masterpiece

The steps taken by Ancient Greeks to create their iconic sculptures

Special accents
Eyes would often be added in bone or glass, as well as copper accents for the lips.

Finishing touches
Statues were painted to make them that little more striking.

In pieces
Multiple pieces were carved separately and then structures such as arms were fixed to the body using wooden dowels.

Buffed up
Once carving was complete, the marble statue would be buffed with an abrasive powder, usually emery.

Quarrying the stone
Quarry workers exploited natural rock fissures and used wooden wedges soaked in water, plus bow drills to extract marble.

Iron tools
Sculptors used heavy iron tools to chip away the initial shape, then much finer tools to create intricate detail.

Topping it off
Many statues would be placed upon a plinth or column and then fixed in place using lead.

© Dreamstime

Inside a Huey

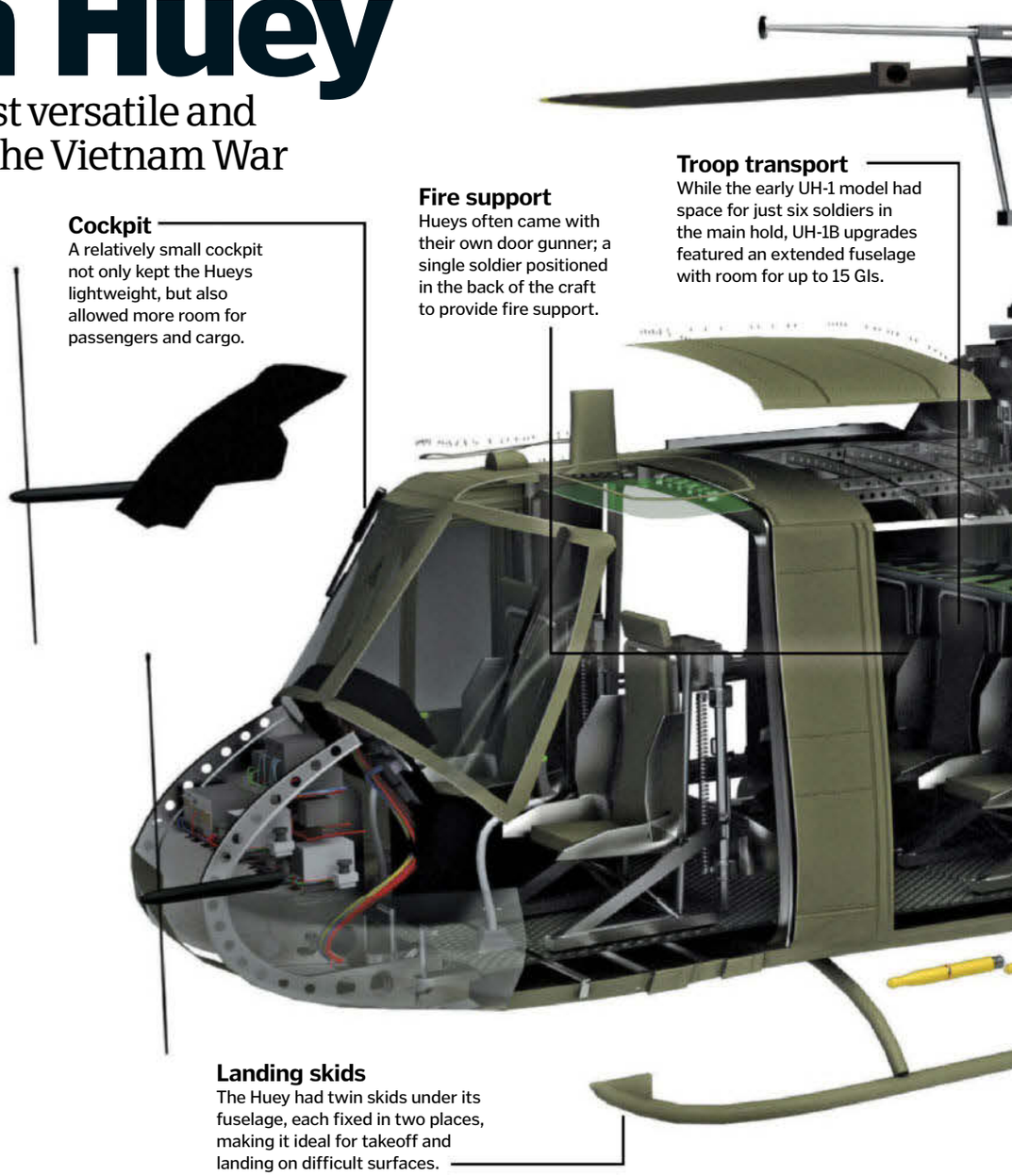
Take a look at one of the most versatile and recognisable vehicles from the Vietnam War

Among the most iconic vehicles of American operations in Vietnam was the multi-functional Bell UH-1 Iroquois helicopter, better known as Huey. With a flexible design, the helicopter was constantly adapted as a rapid troop transport, medevac, supply transport, as well as a gunship. In Vietnam, the American forces were able to strike deep into enemy territory using Hueys, which had an effective range of up to 510 kilometres (317 miles). Parachute drops were hardly ever used during the entire war, mainly due to the hazards of dropping men over thick jungle. Helicopters, on the other hand, were able to deploy units more precisely in designated clearings.

At the Battle of Ia Drang (1965), Hueys were used to drop US troops within Viet Cong territory, but due to the sheer number of soldiers required for the operation, the transports had to make multiple trips between the landing zone and their base. Once the fight began, many of the vehicles then turned to re-supply and evacuation missions as casualties mounted and ammunition ran low. The versatility of the Huey's simple fuselage, its wide doors and large flat base, proved ideal for housing either injured troops or crates of supplies.

However, many Hueys had little to no armament, making them ideal targets for Viet Cong fighters. Over 1,000 were lost during the war, either through accident or enemy attacks, though many of the craft also came armed. Door gunners equipped with either carbines or mounted medium machine guns were often positioned in the hold, poised to defend the Huey or provide fire support for troops below. Later versions of the Huey also came loaded with 30-calibre machine guns and even rocket pods, with which they could assault enemies on the ground.

During its lifetime, more than 16,000 Bell UH-1 models were produced, with 7,000 seeing active service between 1955-1976. Many are still used today by military and civilian organisations worldwide.



Cockpit
A relatively small cockpit not only kept the Hueys lightweight, but also allowed more room for passengers and cargo.

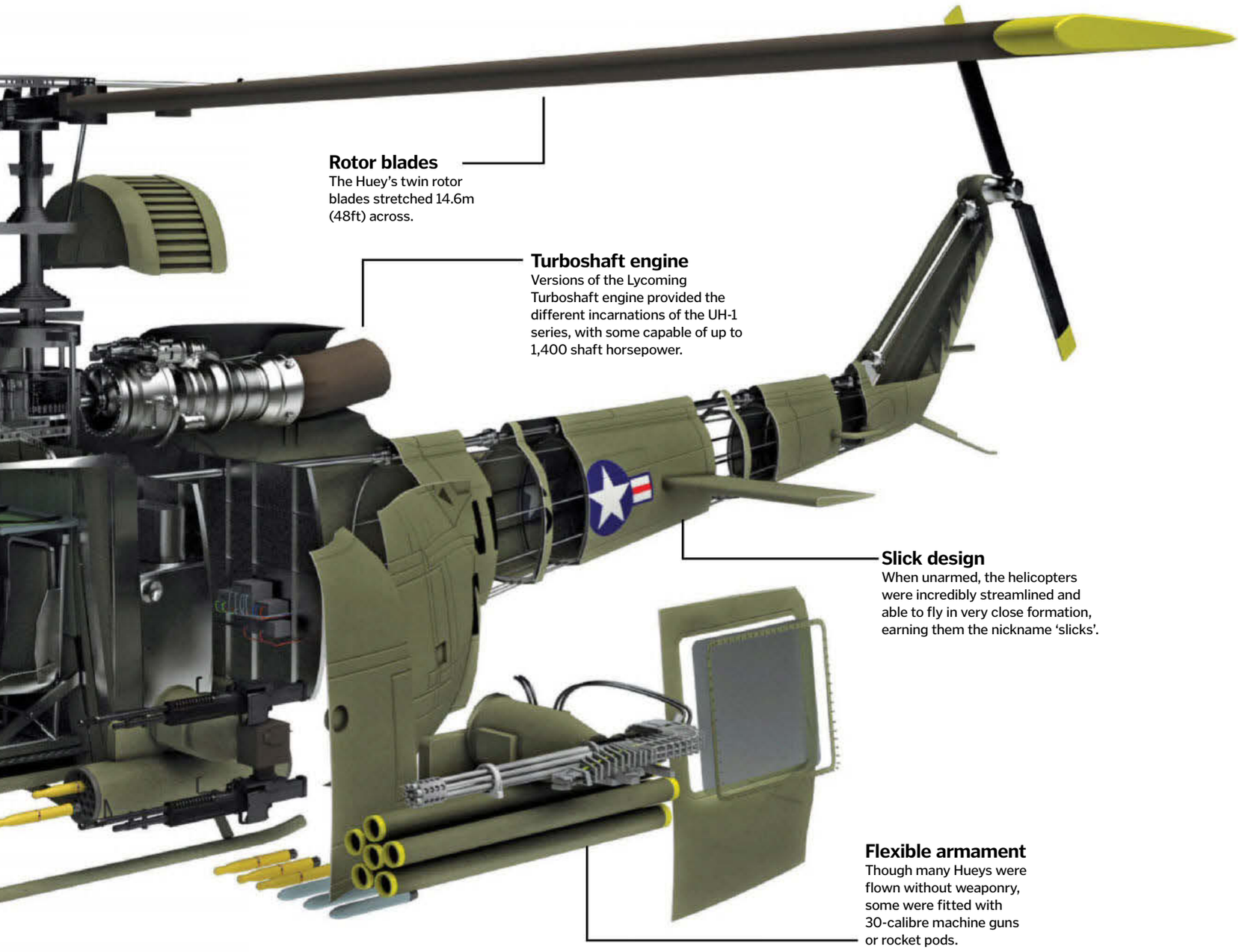
Fire support
Hueys often came with their own door gunner; a single soldier positioned in the back of the craft to provide fire support.

Troop transport
While the early UH-1 model had space for just six soldiers in the main hold, UH-1B upgrades featured an extended fuselage with room for up to 15 GIs.

Landing skids
The Huey had twin skids under its fuselage, each fixed in two places, making it ideal for takeoff and landing on difficult surfaces.

Huey helicopters prepare to transport troops during Operation Wahiawa, South Vietnam

Here a UH-1D is pictured during the Battle of Ia Drang in 1965



Rotor blades
The Huey's twin rotor blades stretched 14.6m (48ft) across.

Turboshaft engine
Versions of the Lycoming Turboshaft engine provided the different incarnations of the UH-1 series, with some capable of up to 1,400 shaft horsepower.

Slick design
When unarmed, the helicopters were incredibly streamlined and able to fly in very close formation, earning them the nickname 'slicks'.

Flexible armament
Though many Hueys were flown without weaponry, some were fitted with 30-calibre machine guns or rocket pods.

The modern 'Super Huey'

Bell's UH-Y1, also called the Yankee and the 'Super Huey', is one of the latest stages in the evolution of the Huey. With all the flexibility, reliability and efficiency of the original UH, this 21st-century beast of the air packs in the most up-to-date military-grade tech. As well as a night-vision-compatible cockpit and an electronic warfare self-protection suite, this modern Huey also notably has two twin rotor blades, unlike the original UH series.

Also different to the original Hueys, the UH-1Y craft have vastly improved safety and protective features, including a crashworthy fuel system and energy-absorbing landing gear. Capable of carrying heavier payloads and flying further than its predecessor, the UH-1Y was deployed in Afghanistan in 2009 where it was utilised by the US Marine Corps.

US Marine Corps pilots landing a UH-1Y during training exercises in Pendleton, California

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BRAIN DUMP

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MEET THE EXPERTS

Who's answering your questions this month?

Luis Villazon

Luis has a degree in zoology from Oxford and another in real-time computing. He builds steampunk gizmos and electronic gadgets, and his articles about science, tech and nature have been published around the world.

Laura Mears

Laura studied biomedical science at King's College London and has a masters from Cambridge. She escaped the lab to pursue a career in science communication and also develops educational video games.

Alexandra Cheung

Having earned degrees from the University of Nottingham and Imperial College London, Alex has worked at many prestigious institutions, including CERN, London's Science Museum and the Institute of Physics.

Hayley Barnes

When she's not out shooting a sunrise, writer and photographer Hayley is researching everything about space, smart animals and biology, among many other things. She thrives on discovering facts about nature, science and tech.

Shanna Freeman

Shanna describes herself as somebody who knows a little bit about a lot of different things. That's what comes of writing about everything from space travel to how cheese is made. She finds her job comes in very handy for quizzes!

A kangaroo's gait enables it to travel long distances with minimal exertion

Why do kangaroos jump?

Hannah Costello

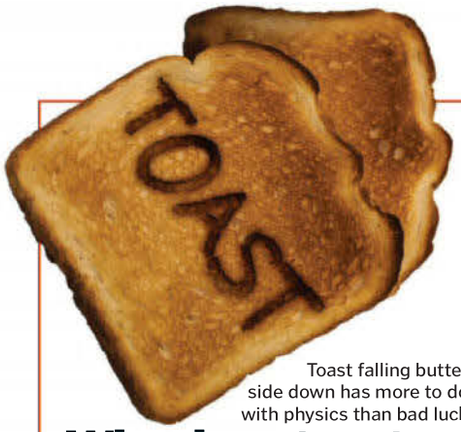
At high speeds, a kangaroo's hopping is considerably more energy efficient than running, enabling these creatures to travel comfortably at average speeds of around 30 kilometres (20 miles) per hour for long periods of time. This ability is key in the barren Australian outback, where animals frequently have to cover large distances in search of food or water. The kangaroo's morphology has evolved to maximise efficiency, with strong, elastic tendons designed to store and release energy. As it hops, the back and forward movement pumps air in and out of its lungs, saving even more energy. **AC**

Human speech is made possible by our unusual anatomy

Why did speech evolve?

Sage Horley

Speech and language are two separate things, but their evolution is linked. Humans are different from other primates because our larynx (voice box) is lower down in our throats. Scientists think that this might have helped early humans to sound bigger and scarier than we really were. Having a low larynx means that we can move our tongues much more freely and make a much wider range of sounds. In the animal kingdom, whales use their vocal repertoire to signal their membership of a family group – individuals learn songs from one another, making it easy to spot an outsider. One hypothesis is that early human speech was used in much the same way, evolving as a mechanism to detect people who didn't belong. **AC**

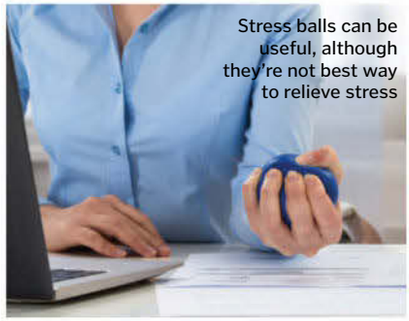


Toast falling butter side down has more to do with physics than bad luck

Why does toast always fall butter side down?

Simon Gale

It's often wrongly assumed that toast falls butter side down because of the added weight of butter on one side. But in fact, weight has no effect on how a slice of toast lands, it's actually all to do with the height that it's dropped from. You'll find if you were to drop toast from the side of your kitchen counter or table, it's more likely to land on the buttered side as these surfaces are around waist height. Therefore, a slice of toast is unable to complete a full 360-degree rotation as it falls. In order for toast to land butter side up, you would have to drop it from much higher up. **AC**



Stress balls can be useful, although they're not best way to relieve stress

Do stress balls actually help to ease the feeling of stress?

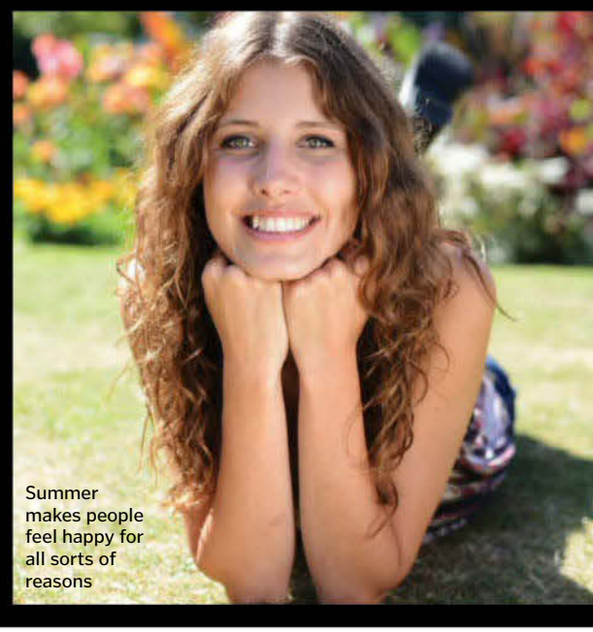
Ross Parsons

Although those little squishy balls may seem useless, there's actually some evidence that they can help. Stress can make your muscles tighten up – it's the fight-or-flight response caused by hormones like adrenaline. If your stress is work-related, though, that energy has nowhere to go. Squeezing the ball creates tension and releasing the ball releases that tension. Just squeezing your hand is a start, but to get the full benefit, you might consider tensing and releasing all of your muscle groups in turn. It's called progressive muscle relaxation. One of the best ways of physically relieving stress, however, is exercise. **SF**

Why does the warm weather lift my mood?

Stephen Green

Happiness is affected by such a huge number of different factors that it is difficult to know if the warm weather is directly responsible, but we do know that the seasons can definitely affect our mood. There is a medical condition called seasonal affective disorder, where sufferers experience episodes of depression at certain times of the year. Most become ill in the winter but some experience symptoms in the summer months instead. The cause of seasonal affective disorder is not yet known, but it is thought to have something to do with hormones produced in the brain in response to daylight. As the days get longer in the summer, the levels of these hormones change. **LM**

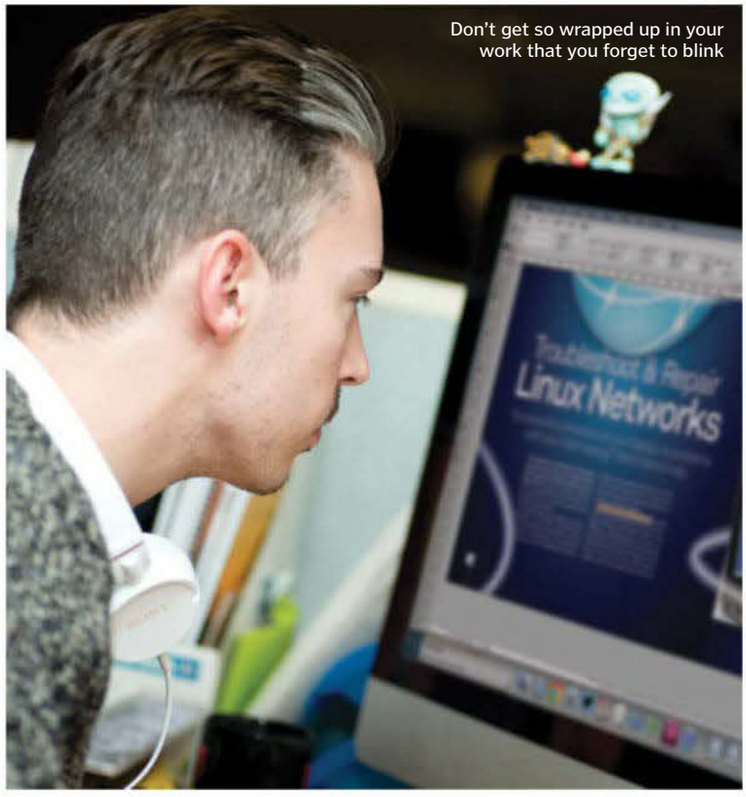


Summer makes people feel happy for all sorts of reasons

Does staring at a computer screen damage your eyesight?

Daniel Aittie

A twenty-year study of 4,500 children in the US recently concluded that there was no link between those that spent the most time in front of a TV or computer and the ones that went on to become shortsighted. But another study found that computer use may increase the risk of glaucoma, particularly if you are already shortsighted to begin with. Glaucoma is a disease where the fluid doesn't flow out of the iris properly, increasing the pressure in the eye and eventually damaging the optic nerve. Regular eye tests should catch this early on though, and it can be treated quite easily with eyedrops. **LV**



Don't get so wrapped up in your work that you forget to blink

FASCINATING FACTS

Which mammal migrates the furthest?

Earlier this year, a female western gray whale was tracked swimming from Russia to Mexico and back again, covering a huge distance of 22,511km (13,988mi).

Gray whales can migrate thousands of miles to their breeding grounds

BRAIN DUMP

Moths are naturally drawn to light but there only theories as to why this is

Why are moths attracted to light?

Ben Ferry

We know moths as a species are positively phototactic, which means they are naturally drawn toward light. However, exactly why they're attracted has yet to be scientifically proven, but there are a few likely theories. In fact, a behaviour called transverse orientation could explain the phenomenon. This is where an insect will use a distant natural source of light, such as the Sun or Moon, as a reference point to help them navigate. So it's possible that a moth can be disorientated by artificial light and fly toward it in confusion. **HB**

When built-up steam is forced out of the kettle chamber it creates vortices that produce the signature whistle

Why do kettles sometimes whistle?

Victoria Armour

The high-pitched whistling sound produced by a classic stove kettle is designed to alert you when the water inside reaches the boiling point. The actual whistling sound is created when built-up steam is forced to escape through the steam whistle, which is attached to the end of the spout. The steam whistle features two narrow holes that restrict the flow of air. The first opening contracts the steam as it enters and creates a concentrated jet of steam. The jet, however, loses stability as it passes through the whistle towards the exit hole, much like a jet water from a hose will begin to break into droplets after a certain distance. This means that the steam can't flow steadily out of the whistle and will instead bounce off the whistle wall, creating vortices. It is these vortices that produce the well-known whistling sound of a kettle. **HB**

FASCINATING FACTS

What is the Universe made of?

Less than 5% of our universe is normal matter made of atoms – the rest is made up of invisible, mysterious substances called dark energy and dark matter (roughly 70% and 25% respectively).

Little is known about most substances that make up our universe

What is the Rosetta Stone?

The Rosetta Stone is a slab carved in 196 BC with a decree passed by a council of Egyptian priests. The decree is in three different scripts and two languages, which let Egyptologists decipher hieroglyphs.

The British Museum has displayed the Rosetta Stone since 1802

What is the world's largest building?

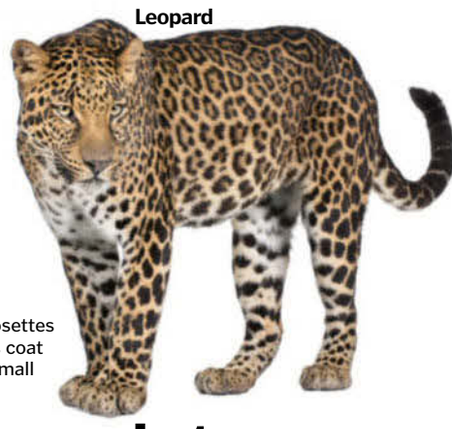
The Boeing Everett Factory has the largest volume, at over 13.3mn m^3 (472mn ft^3). But the New Century Global Center in Chengdu, China, is the largest by floor area, at a whopping 1.7mn m^2 (18mn ft^2)!

The New Century Global Center contains hotels, offices and even an artificial beach

How do insecticides kill creepy crawlies?

Barry Frier

There are many types of insecticides and each works in a different way. Old-fashioned insecticides, like organophosphates and DDT, attack the nervous system. They are effective but they don't just work on insects and can cause serious harm to humans. Newer insecticides are made to specifically target unwanted species. The insecticides used to kill fleas on your dog stop the insects producing a new exoskeleton, preventing them from shedding their skin. Other insecticides used to kill beetle and moth infestations, contain chemicals that mimic insect growth hormones, keeping the insects in a juvenile state to stop them reproducing. **LM**



The larger rosettes on a jaguar's coat often have small dots inside

What's the difference between a jaguar and a leopard?

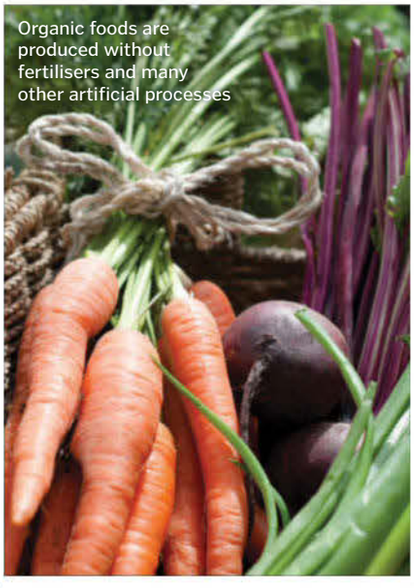
Francis Bullen

It can be difficult to tell these two big cat species apart, but usually you can look closely at the patterns on their fur. Both jaguars and leopards have rosette patterns, but the rosettes on a jaguar's coat are usually larger, and tend to have spots inside of them (unless they're melanistic, or black). Another way to tell the difference is by their body shape and size. Leopards have longer tails and longer, leaner bodies, while jaguars are usually more compact and have broader heads. Jaguars live in South America, while leopards can be found across Africa and Asia. **SF**

What makes food organic?

Ted Purvis

The requirements needed for a food to be labelled as organic vary from country to country but they generally include avoiding unnecessary chemicals (such as fertilisers), genetically modified crops and certain types of processing. Limited use of pesticides is allowed, however. Livestock raised organically meanwhile, enjoy higher welfare standards. However, there are a number of controversies surrounding organic food and its health benefits. While many in favour of organic food suggest that it is more nutritious, most studies indicate that this is not necessarily the case. Although organic food contains fewer pesticides, conventional food still has pesticide levels well below what is considered unsafe to consume. **AC**



Organic foods are produced without fertilisers and many other artificial processes

Tie your shoelaces vigorously enough and you might fool it into counting some extra steps

How do fitness trackers count your steps?

Kim Jenkins

Electronic fitness trackers have accelerometers that use micro-electro-mechanical systems (MEMS) technology. They consist of a pair of three metal plates sandwiched together. The middle one has a counterweight that can move in response to sudden accelerations. This moves the middle plate slightly closer to the outer plate on one side or the other, which can be detected as a change in the capacitance between the plates and converted into a measure of the acceleration. Three of these tiny accelerometers are packed at right angles to each other on the same chip, so the fitness tracker can measure the movement of your wrist in three dimensions. Since you swing your arms as you walk or run, software algorithms can translate this into the number of steps you have taken. Most trackers are only around 90 per cent accurate, though. **LV**

How can we stop acid rain?

Joseph Newell

Acid rain is precipitation that has high levels of sulphuric and nitric acids, and human activity causes most of it. Burning fossil fuels release sulphur dioxide and nitrogen oxide that react with atmospheric gases and the resulting acid rain can harm both animals and plants. To prevent acid rain, we must reduce emissions and curb the burning of fossil fuels, which means finding alternative fuel sources. As an individual, you can reduce your impact by using public transportation, walking, cycling, carpooling and cutting back on your overall use of electricity. **SF**

The effects of acid rain on the woods of the Jizera Mountains in the Czech Republic

BRAIN DUMP

Voyager 1 captured the first "sounds" of interstellar space

Is there sound in space?

Natalie Aldridge

Sound exists as waves that travel through air, but in space there's no air through which these waves can travel. However, in 2013 a NASA physicist announced that he had recorded sounds in interstellar space. Don Gurnett used an instrument that detects the electromagnetic vibrations that electrons make as they travel through plasma. They aren't sound waves, but they do pulse at similar frequencies. Once the data was recorded and processed, it could be heard as sound. Gurnett was seeking proof that Voyager 1 had left the heliosphere. It picked up audible tones that were very low at around 300 hertz as it travelled inside, thanks to bursts of plasma called solar storms. Once the ship left the heliosphere and began travelling through interstellar medium, the frequency changed to between two and three kilohertz because the gas there is denser. So there is not true 'sound' in space, but you can hear something if you have the right knowledge and instrumentation. **SF**

FASCINATING FACTS

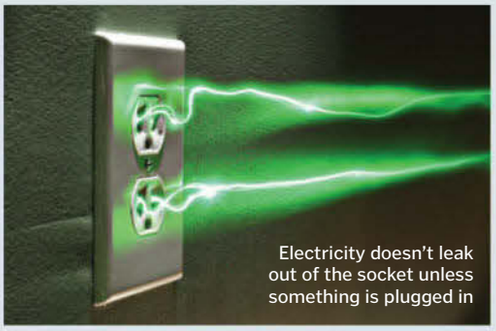
How fast can a woodpecker peck?

According to a study conducted at Beihang University in China, woodpeckers move their heads at speeds of up to seven metres (23 feet) per second, that's over 25 kilometres (15 miles) per hour.

If a plug socket is switched on but there is nothing plugged in, is it wasting power?

Joseph Newell

No. The switch on a wall socket just connects the live wire to the pin in the plug. It's there to provide a convenient way to switch off devices that don't have a on/off switch. But there's no difference between a wall socket that is switched on and a socket that doesn't have a switch at all. Those sockets are live all the time but they don't use any power until something is plugged in to complete the circuit between the live and neutral pins. There is no 'standby power' for a wall socket because they don't have any electronics inside them. **LV**



Electricity doesn't leak out of the socket unless something is plugged in

Trees would be among the first species to die on a sunless Earth

How long could we survive for when the Sun dies?

Nicholas Clarke

If the Sun suddenly died, Earth would be transformed into a cold, dark, lifeless planet in a matter of weeks or months. Without the Sun's energy, no photosynthesis could occur, spelling the end for all plant life within weeks. The Earth's surface temperature would drop off, reaching temperatures below freezing within a few days. With no plants around, plant-eating species would be next to go as they exhausted food supplies. If they could endure the cold, meat-eating species including humans could survive for a while, although their food would soon run out too. From then onwards, how long humans could survive for would depend on their ingenuity and technology. A nuclear fusion reactor for instance, might enable us to sustain ourselves. However, in reality, the Sun's death will occur over millions of years and our star will first increase in intensity and dry out the planet's water, ending all life on Earth long before its own death. **AC**

Microrganisms that live in a dog's fur are responsible for the wet dog stench

What causes the wet dog smell?

Rebecca Willets

The smell of wet dog is pretty unpleasant. This distinct aroma actually comes from the excrement of small microorganisms, such as yeast and bacteria, which live within the animal's fur. When these organisms come into direct contact with water, it breaks their chemical bonds, which in turn releases musky molecules into the air. Leaving a wet dog to air dry can make the odour considerably more pungent. This is because when water evaporates off a surface it creates a relative humidity around it. As humid air can hold more molecules, this means you will get a much stronger whiff of wet dog. **AC**

Almost all cheese rinds are safe to eat – although not necessarily tasty

Can you eat the rind on cheese?

Paloma Daniels

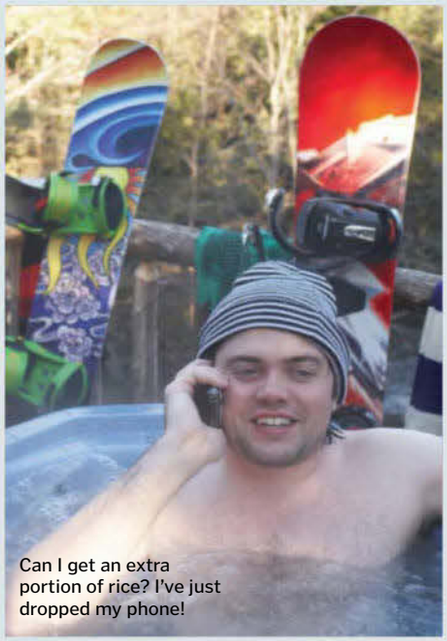
Cheese rinds are safe to eat, bar a few exceptions where the cheese is coated in a layer of wax. Rinds form when bacteria and fungi colonise the outside of cheese, changing its appearance, taste and texture. There are three main types of rind. Bloomy rinds, found on brie for example, form after cheeses are sprayed with penicillin spores. Washed rinds result from regular baths in brine or alcohol. Finally, natural rinds (parmesan, for example) develop when a cheese is allowed to age naturally, forming a hard crust as it dries out. All are edible, although many find the hard texture of natural rinds unappealing to eat. **LM**

Why is hot water better for washing than cold?

Alicea Laurence

Hot water works better than cold water when doing the dishes for the same reason that sugar dissolves faster in a cup of hot tea. According to the second law of thermodynamics, as the temperature rises, the water molecules gain more energy. They move around more quickly and bash into your dishes at higher speed, making it easier for them to pull particles into the dishwater. When washing your clothes though, hot water isn't always better. Old-style detergents use chemical machines called enzymes to break down the dirt on your clothes, and these work best at around 30-40°C (86-104°F). However, new detergents are designed to work just as well at lower temperatures. Turning your washing machine's temperature down saves both energy and money, while keeping your clothes looking their best for longer. **LM**

Hot water isn't always the most effective option, but it works well for dishes



Can I get an extra portion of rice? I've just dropped my phone!

Does putting your wet mobile phone in rice really dry it out?

Harriet Snowden

All water, except distilled water, contains impurities that make it electrically conductive. This will short-circuit the battery destroying it within seconds and no amount of rice will save you. So the most important thing is to remove the battery immediately – don't even wait to power down first. Packing it in dry rice for 24 hours after that will help to absorb the water that might corrode the electrical contacts or get trapped under the screen. But dismantling it as much as possible and leaving the parts in a warm airing cupboard is just as effective. **LV**

New Brain Dump is here!

Don't miss issue 28 of **Brain Dump**, the digital sister magazine to **How It Works**, when it lands on the virtual newsstand on 3 September. You'll find out how high balloons can float if you let go, how birds know when to migrate and whether eating fish really is good for your brain. Also in this issue: the smallest frog in the world and how to make a water rocket! Every edition is packed with stunning images and fun facts to entertain your friends and family with. Download the new issue of **Brain Dump** at the beginning of every month from iTunes or Google Play. If you have a burning question, you can ask at **www.facebook.com/BraindumpMag** or Twitter – the handle is **@BrainDumpMag**.

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THE WISH LIST

The tech behind the latest must-have gadgets

Survival tech

The latest gadgets that will keep you alive when out in the wilderness

1 Keep track of nearby threats

G42NG stealth camera

£189.99 / $189.99

www.gsmoutdoors.com

Even the most experienced survival expert doesn't have eyes in the back of their head. The G42NG stealth camera goes some way to solving this, enabling users to monitor important locations and become fully aware of their surroundings with the help of this camouflaged 10-megapixel camera. It works by sensing movement, and is capable of detecting someone or something up to 30.5 metres (100 feet) away with the help of its infrared emitters and low-light sensitivity.

Once movement is identified it instantly begins recording video; the user can then review the footage so that they know the dangers present in their current area. An additional feature of the stealth camera is its ability to add a GPS tag to each photo or video that it takes – great when comparing footage or checking which animals were spotted in different locations. The camera is battery powered which isn't ideal, but these are easily interchanged and spares can be carried.

HD video recording
The G42NG will record between five and 180 seconds of video, complete with sound.

HOW IT WORKS EDITOR'S CHOICE AWARD

Expandable storage
The camera comes fitted with an 8GB storage card, but can be expanded to store 32GB of covert video.

© CCG GT Textures

SOS flashlight
This SOS beacon activates Morse code signals.

2 Signal an SOS

Midland ER300 Emergency Crank Radio
$79.99 (approx £50)
www.amazon.com
Powered by either solar energy, rechargeable battery or by hand crank, the Midland ER300 Emergency Crank Radio is the perfect survival accessory if you don't want to be caught out by the weather. This radio is not only equipped to flag up severe weather, it has a number of extra handy features for a survival situation. Its SOS flashlight beacon activates Morse code to help signal the emergency services, and it even has an ultrasonic dog whistle to help search and rescue teams find your position. The ER300 is both rugged and compact, and could be worth every penny if you ever got lost or injured in the great outdoors.

Lashing straps
There is even a space to attach lashing straps, so that your Kniper can be securely attached to either you or your bag.

Multiple blades
The Kniper is fitted with a small saw blade that can cut through branches easily, particularly useful when building a shelter.

3 Ultimate survival knife and multi-tool

Kniper
$145 (approx £95)
www.urchinsky.com
Milled from a single piece of high-carbon stainless steel, the Kniper is much more than just a throwing knife. Featuring 22 tool functions, the Kniper aims to meet all of your survival needs without compromising its ability to be thrown accurately, and makes carrying a separate pocketknife completely unnecessary. The Kniper is 33 centimetres (13 inches) long and 6.35 centimetres (2.5 inches) wide, making it the perfect size for most camping bags or rucksacks. It can remove nails; pry things open and even be used as a fork, making it a valuable companion during any survival situation.

4 Watch your location

Garmin epix
£419.99 / $549.99
www.garmin.com
With the entirety of Europe preloaded and space for an additional 8GB of maps, the epix caters for all your navigation needs and more. It has a GPS antenna that provides quick and accurate location details, and has precise sensors that function as a barometer, altimeter and compass. The epix is able to monitor you as well as your global position. It is compatible with a variety of sensors that can function to monitor heart rate and temperature, making it fully customisable to match your needs. It is also incredibly durable, allowing it to withstand the tough conditions that you may encounter when out in the wild.

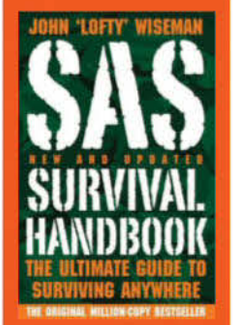
EXTRAS

A few added aids to help you make it out alive

BOOK

SAS Survival Handbook

£12.79 / $14.68
www.amazon.com
This definitive guide comes from ex-SAS survival expert John 'Lofty' Wiseman, and features an array of tips on preparation, navigation, food, health, and disaster survival, helping you feel ready for any dangerous situation that you may be confronted with.



APP

Cures A-Z

Free
iTunes or Google Play
This app is the ultimate guide to natural remedies and is a great way to educate yourself about what you need to cure a range of ailments. This knowledge could ultimately prove life-saving in a survival situation, especially if you're unable to get medical help.

WEBSITE

OffGrid Survival.com

Although it doesn't follow the traditional survival blog layout, Off Grid Survival is well worth exploring. This encyclopaedic site provides the reader with valuable information via links to various articles that explain survival tips.

5 Paracord on your wrist

Bear Grylls Survival Bracelet
£19.99 / $20.62
www.gerbergear.co.uk
From building a primitive bow to lashing together timber to form a shelter, the list of possible uses for good-quality rope in a survival situation is endless. The Bear Grylls Survival Bracelet enables you to keep 3.66 metres (12 feet) of high-strength paracord with you at all times, ready for when you need it. The bracelet weighs less than your average watch, and fits snuggly to any wrist thanks to the adjustable straps. Cleverly concealed within the bracelet is an emergency whistle to help signal for help if you suddenly find yourself in harm's way.

6 Produce your own drinking water

LIFESAVER bottle 4000UF
£119.99 / $149.95
www.lifesaversystems.com
The availability of clean drinking water can make the difference between life and death in a survival situation. LIFESAVER technology is the first example of portable water filtration that is proven to remove all waterborne bacteria, viruses, cysts and parasites, by filtering down to an incredible 15 nanometres (over 5,000 times smaller than the thickness of a human hair). This ensures that the smallest known waterborne virus (parvovirus, measuring 18 nanometres) is filtered out. The LIFESAVER can be used anywhere by merely filling it with water and pumping it through the filter. This simple design makes it perfect for any location, costing you only three pence (five cents) per litre (0.26 gallons).

Smart filter
Can remove the smallest known waterborne virus.

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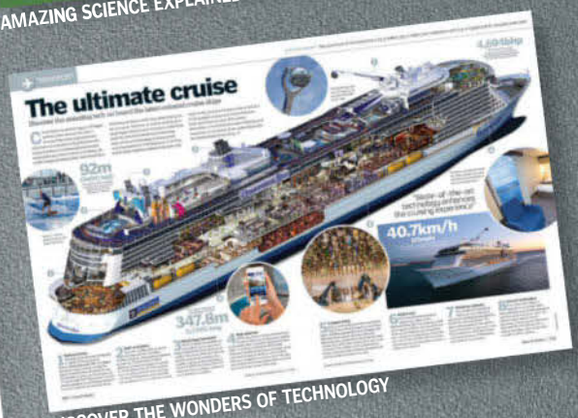

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Build an electric motor

Find out how everyday items can turn electric energy into motion

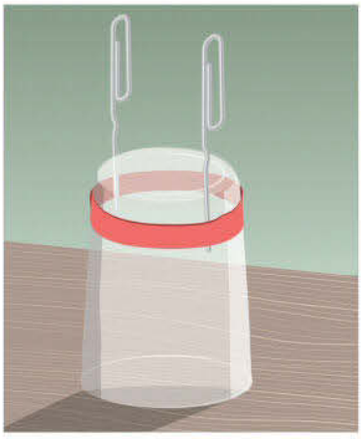
1 Create your electromagnet coil

Make a coil with a long piece of insulated wire, about 0.9 metres (three feet) long. Wrap it tightly around a D-cell battery at least seven times. Do this evenly, as an uneven distribution of weight will mean the coil is unable to rotate properly. Tie off the coil by wrapping the ends around the middle to hold it together, as pictured, and then strip the insulation from both ends.

DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU

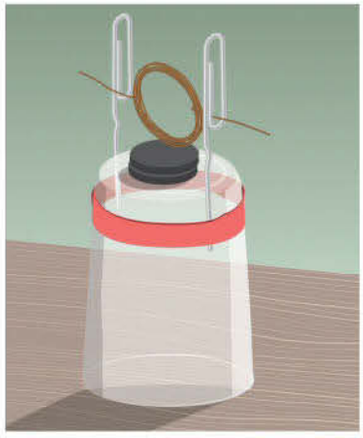
2 Prepare your paper clips

In this experiment the paper clips serve several purposes. They need to be able to support the coil and enable it to rotate freely, as well as conduct electricity to the coil. Using your fingers, or pliers if you find it easier, straighten out the larger loops in two paper clips. The remaining loop in each paper clip will support the ends of the coil once the motor is assembled.



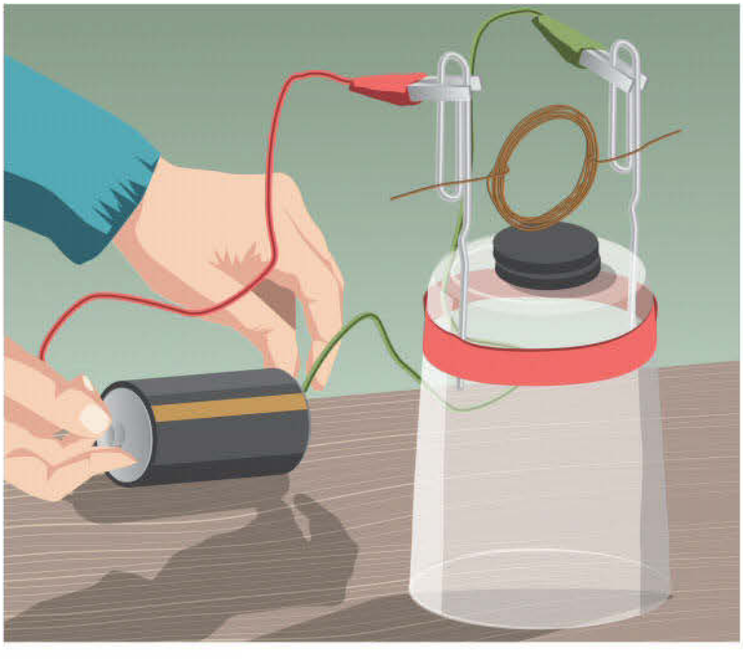
3 Attach your paper clips

Take your plastic cup and place it upside down on a flat surface. You may prefer to cut this so that it has less height, but this is difficult to do evenly so we recommend leaving the cup whole instead. To attach the paper clips, place two rubber bands around the plastic cup and slot the ends of the paper clips in between them. Make sure that the paper clips are secure and level.



4 Insert your coil and your magnet

Place two disc magnets in the centre of the plastic cup's base, one on top of the other. Next, rest your coil in the paper clip loops and adjust the height of the paper clips so that the coil is able to spin and just clears the magnets. It's important to adjust the coil so that it will remain balanced and centred when it spins on the paper clips, as this is key to the overall motor's function.



5 Finish your motor assembly

Attach a clip cable to each paper clip and hold the opposite ends of each cable to either end of a D-cell battery. The coil should spin and will align with the magnets due to the current you've created. If the coil doesn't spin, you may need to turn off the current once the coil and magnets are aligned. This can be achieved by painting the top half of one of the wires' two bare ends with a permanent marker. Congratulations, you've built a working electric motor!

In summary...

This simple experiment is a great way to see how a magnetic field is produced from an electric current. Using a permanent magnet enables the magnetic field to be attracted or repelled which can cause movement in a wire that is carrying an electric current.

Disclaimer: Neither Imagine Publishing nor its employees can accept liability for any adverse effects experienced after carrying out these projects. Always take care when handling potentially hazardous equipment or when working with electronics and follow the manufacturer's instructions.

NEXT ISSUE
- How to extract your own DNA
- How to make sugar crystals

Clean tarnished silver

Learn how to return your tarnished silver to its former gleaming glory

1 Prepare your cleaning pan

To begin, you need to find an aluminium cleaning pan for your silver. This pan should be big enough to fully immerse your silver in the cleaning solution, so ensure you choose accordingly. It is imperative that your silver is in direct contact with the aluminium during the cleaning process. If you don't own an aluminium pan, you can line another one with aluminium foil.

2 Prepare your cleaning mixture

Boil an appropriate amount of water; this will form the base of your cleaning solution. Pour the boiling water into a large bowl in your sink. To the boiling water, add roughly one cup of baking soda for each 4.5 litres (1.2 gallons) of water. Be careful when you do this as the mixture will froth and may spill over, which is why it is mixed in a separate bowl rather than directly in your cleaning pan.

3 Clean your silver

Place your tarnished silver into your cleaning pan and cover it with the hot water and baking soda mixture. The tarnish should start to disappear; if the silver is only lightly tarnished it's likely to disappear within two to three minutes. If the tarnish is severe, you can reheat your cleaning mixture and treat the silver again. Once you're happy, dry your silver quickly, as leaving it wet may cause staining.

In summary...

Silver tarnishes as it can combine with sulphur and form silver sulphide, which is a black substance that will darken the surface. In this experiment, the silver sulphide is removed due to its ability to react with aluminium. The sulphur atoms are transferred to the aluminium from the silver, removing the tarnish and forming aluminium sulphide instead.

WIN!

A wearable fitness tracker

The Withings Pulse O2 fitness tracker can monitor your heart rate and blood oxygen levels as well as your sleep and steps. Your stats are displayed via an app available on both iOS and Android that connects to the device via Bluetooth.

Which animals kill the most humans each year?

a) **Mosquitoes** b) **Spiders** c) **Snakes**

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We enjoy reading your letters every month, so keep us entertained by sending in your questions and views on what you like or don't like about the mag. You may even bag an awesome prize for your efforts!

AMAZING PRIZE FOR NEXT ISSUE'S LETTER OF THE MONTH!

TRAKDOT KEEPS TRACK OF YOUR PRECIOUS LUGGAGE

The Trakdot gives peace of mind for travellers, by alerting them that their baggage has arrived safely. It uses the local cellular network to connect to your mobile, enabling it to work anywhere in the world.

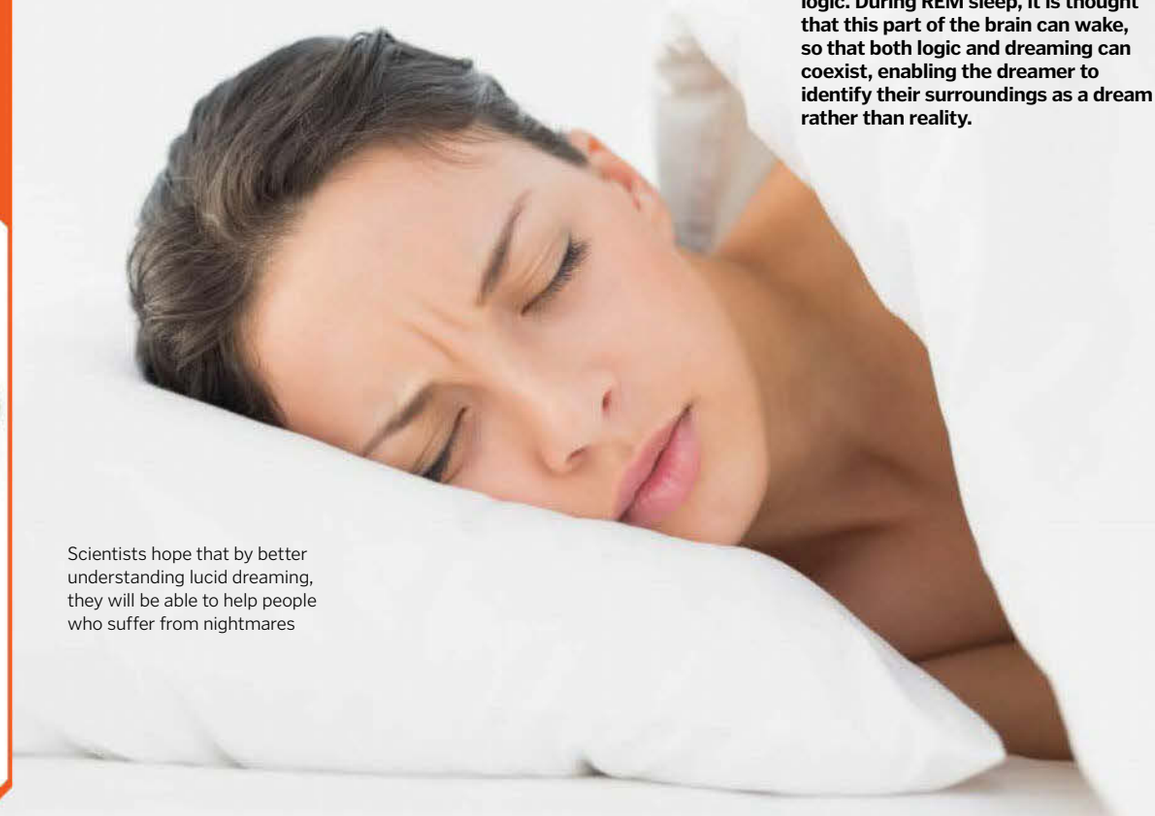
Letter of the Month

Lucid dreaming

Dear **HIW**,
I love your magazine and can't wait to read the new issue each month. Recently I heard about lucid dreaming and I found the idea very interesting. I was wondering if you could explain what lucid dreaming actually is and how exactly it works?
Thank you for creating such a high quality magazine!
Ben Sullivan

Thanks for your question, Ben. During a lucid dream you are aware that you're dreaming; there's essentially a point where you realise that your surroundings aren't real. Although the concept of lucid dreaming and the potential to control your dreams sound unlikely, there is some real science behind it.

Lucid dreaming is possible during the fifth sleep stage, which is known as Rapid eye movement (REM) sleep. Apart from the eyes, the body is almost entirely paralysed, which means the only way subjects can signal to scientists that they are having a lucid dream is by moving their eyes. Why people are able to have lucid dreams is still under dispute, but the leading theory relates to a part of the brain called the lateral prefrontal cortex, which deals with logic. During REM sleep, it is thought that this part of the brain can wake, so that both logic and dreaming can coexist, enabling the dreamer to identify their surroundings as a dream rather than reality.



Scientists hope that by better understanding lucid dreaming, they will be able to help people who suffer from nightmares

Can urine power your car?

Dear **HIW**,
I'm a yearly subscriber and love your magazine! I was wondering whether it was possible to convert urine into fuel that can power a car?
Thanks
Chris Jones

The idea of converting urine into a usable fuel has been around for a number of years and there are several different ways it can be done. One simple design was created to extract hydrogen from urea, the main component of urine, and use this to power a car. Hydrogen isn't bonded as tightly to the nitrogen in urea as it is to oxygen in water, so less energy is required to extract it this way. The world produces around 10.5 billion litres (2.8 billion gallons) of urine per day, so there is highly unlikely to be a shortage of this potential fuel at any point in the near future.

Extracting hydrogen from water is expensive, which is why scientists believe urine may be a more viable source of fuel

Will the universe run out of energy?

Dear **HIW**,
I would like to start off by saying that I thoroughly enjoy reading **How it Works** and I am always excited when the latest issue comes out! Due to the fact that the universe is constantly expanding and we still hold the conservation of energy law true, is it possible that the universe will eventually run out of energy?
Thanks,
Gabriel Bauernfreund (age 15)

According to certain theories, at some point in the distant future the universe will run out of usable energy. If the universe continues to expand, eventually everything in it will reach the same temperature. This phenomenon is known as maximum entropy, where all the energy in the universe will be evenly distributed and no further work can be done to change it. Physicists have named this event "the heat death of the universe."

It's thought that even black holes will eventually evaporate, becoming pure energy that will dissipate throughout the universe

© NASA; Thinkstock

It is hoped that car parks will eventually have wireless charging points, so that cars can be recharged while they are parked

"When electricity passes from the wall socket to the coiled wire, an electromagnetic field is created"

Wireless charging

Dear **HIW**,
Our school receives your magazine every month and we are huge fans of all your interesting articles! We have recently become interested in wireless charging and we were wondering how this is able to transfer power without any wires?
Yours sincerely
Nicolas and Toby

Wireless charging is a form of inductive charging as it relies on electromagnetic induction to work efficiently. Typically, it uses coils of wire, one in the transmitter (charger) and one in the receiver (the device to be charged). When electricity passes from the wall socket to the transmitter coil, a magnetic field is created which can then generate a current in the receiving coil. The current is then used to charge the device's battery. Improvements in this technology have enabled large wireless chargers to be created; in South Korea there are sections of road that can recharge electric buses!

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@Burnden1983
@HowItWorksmag great for young children who are in school!

@destinylover09
@HowItWorksmag My husband is in his element with this magazine!

@neiltyson
In 5-billion years the Sun will expand & engulf our orbit as the charred ember that was once Earth vaporises. Have a nice day.

@RichardDawkins
Every one of us has lots of things we don't understand. The trick is to realise it. As well as tides, I also don't understand the bicycle.

@vickywoollaston
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The greatest enemy of knowledge is not ignorance; it is the illusion of knowledge.

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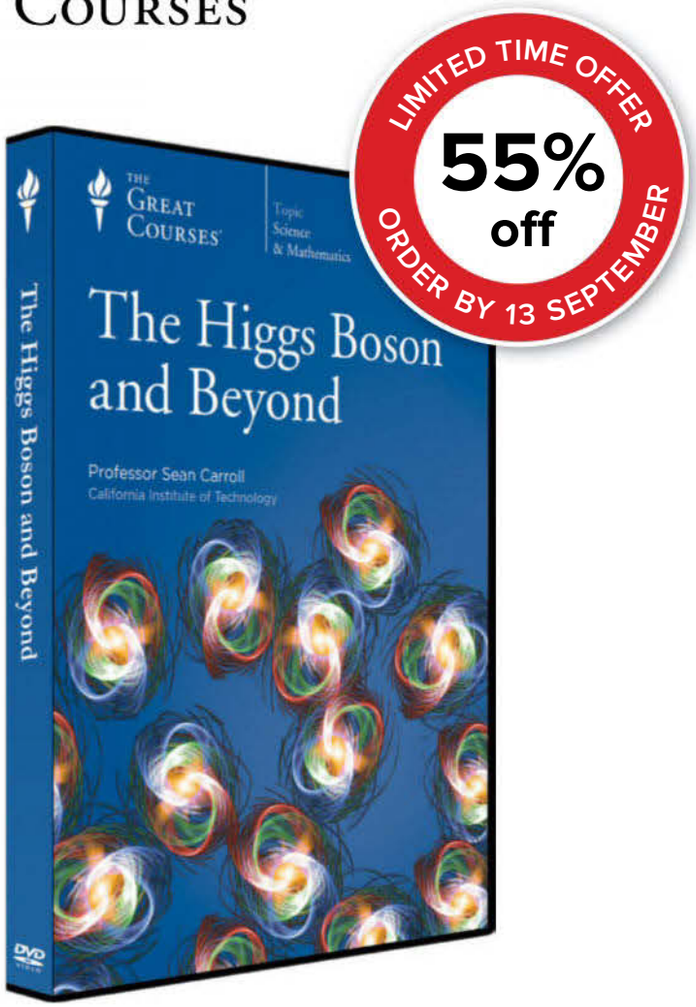

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